Industrial Automation

(Automação de Processos Industriais)

PLC Programming languages

Ladder Diagram

http://www.isr.tecnico.ulisboa.pt/~jag/courses/api20b/api2021.html

Prof. Paulo Jorge Oliveira, original slides
Prof. José Gaspar, rev. 2020/2021

Syllabus:

Chap. 2 – Introduction to PLCs [2 weeks]

...

Chap. 3 – PLC Programming languages [2 weeks]

Standard languages (IEC-61131-3):

Ladder Diagram; Instruction List, and *Structured Text.*

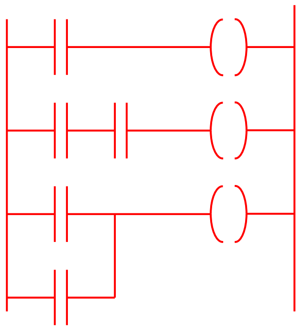
Software development resources.

...

Chap. 4 - GRAFCET *(Sequential Function Chart)* [1 week]

PLC Programming languages*
IEC 1131-3 changed to IEC 61131-3

Ladder Diagram



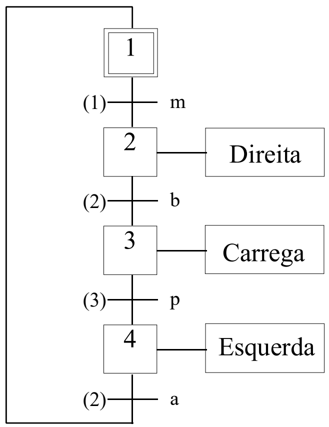
Structured Text

```
If  %I1.0  THEN
  %Q2.1 := TRUE
ELSE
  %Q2.2 := FALSE
END_IF
```

Instruction List

```
LD      %M12
AND     %I1.0
ANDN    %I1.1
OR      %M10
ST      %Q2.0
```

Sequential Function Chart (GRAFCET)



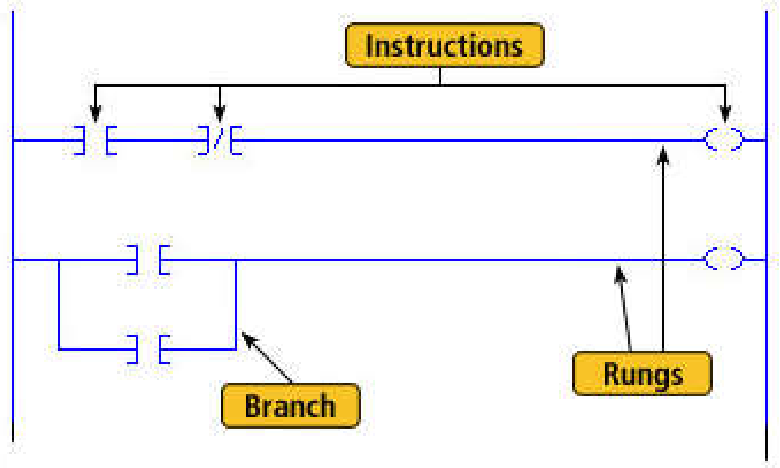
* International Electrotechnical Commission (IEC)

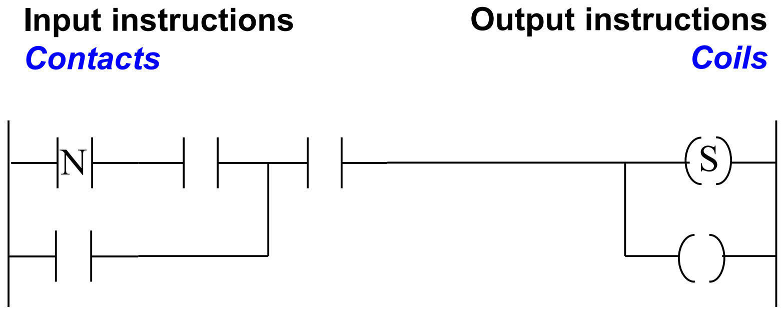
Ladder diagram

Relay ladder logic, i.e. electromagnetic relay control, was the basis to create a standard programming language.

A **Program** is a series of instructions that directs the PLC to execute actions.

Simplest programs are based in **physical addresses** naming **contacts** and **coils** or, in general, the so-called **operands**.





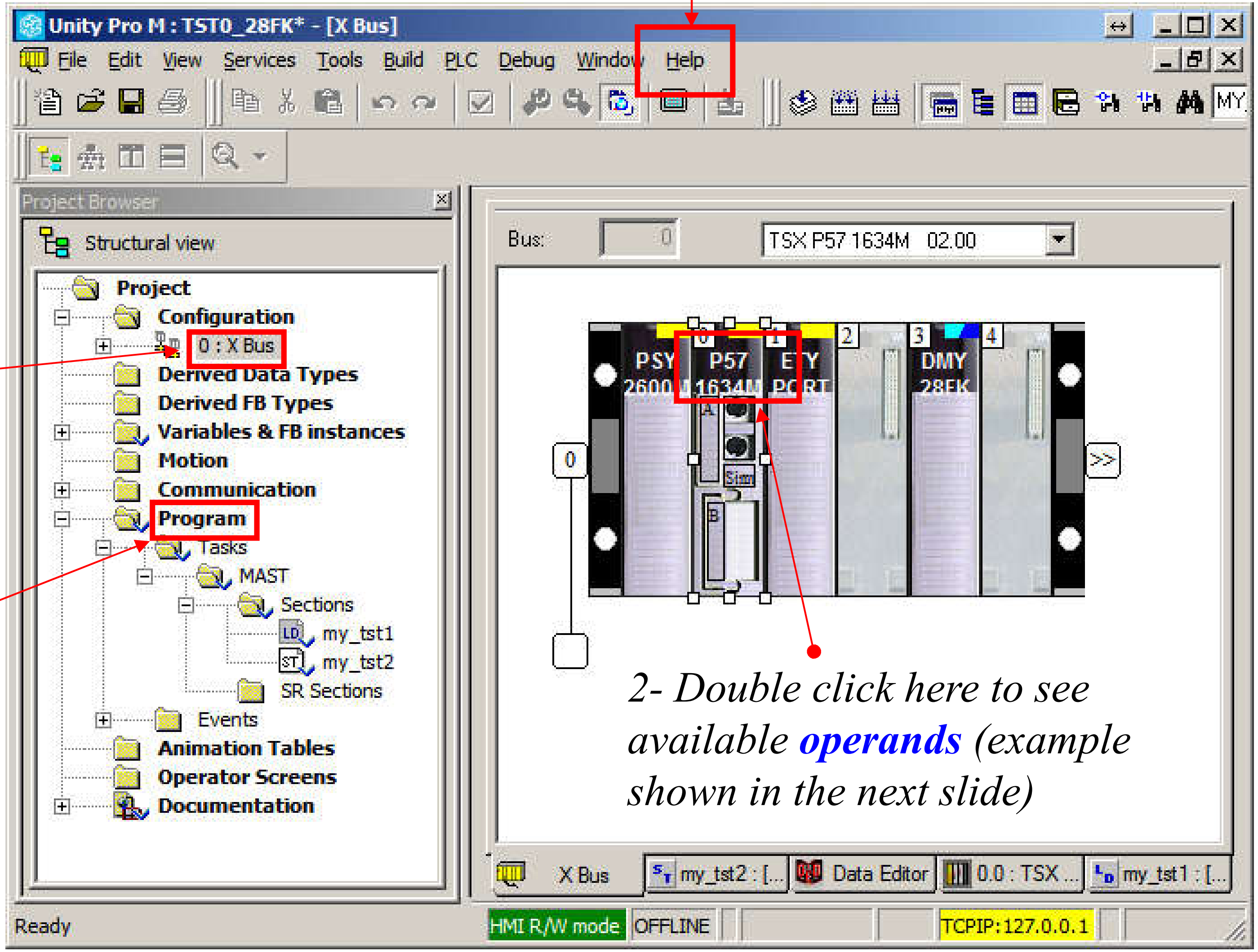
Ladder diagram

Unity Pro dev. environment

0- See: Unity Pro SW > Languages Ref > Programming Language > Ladder Diagram (LD)

1- Double click here to edit / see the ***hardware*** *configuration*

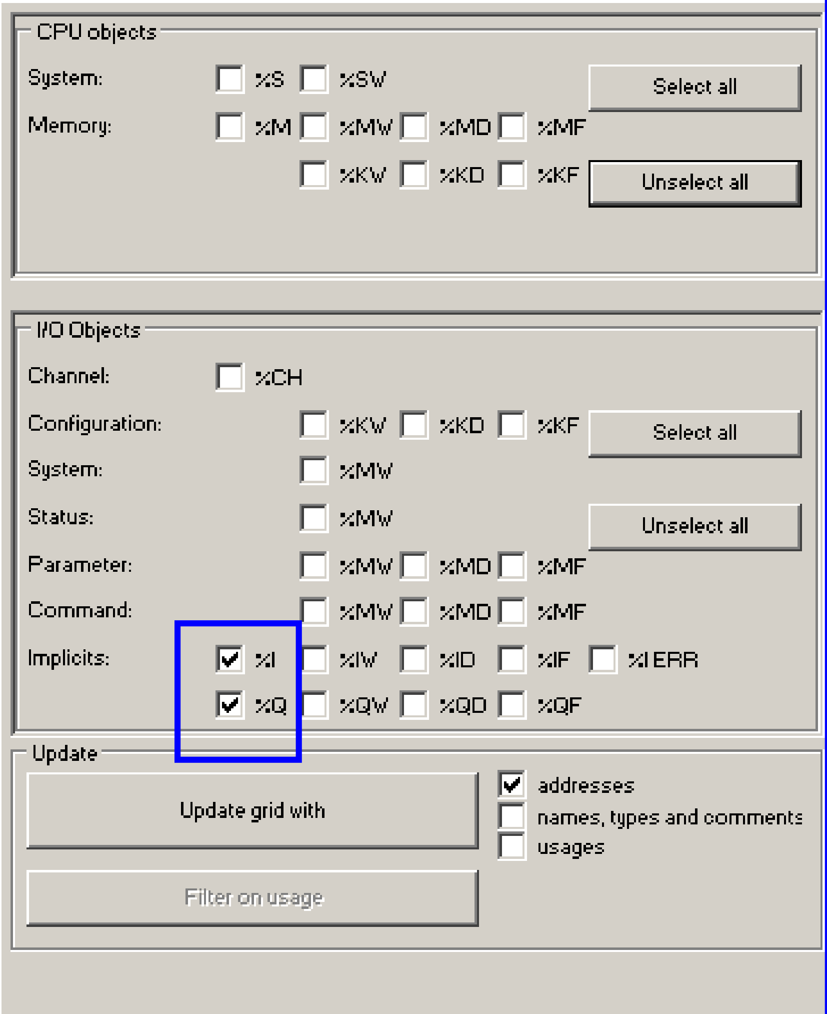
3- Programs in ***Ladder*** *(and other languages) are added here.*



2- Double click here to see available ***operands*** *(example shown in the next slide)*

Ladder diagram

Types of operands in Schneider DMY 28FK:



	Address	Name	Type	Comment
1	%I0.3.0		EBOOL	
2	%I0.3.1		EBOOL	
3	%I0.3.2		EBOOL	
4	%I0.3.3		EBOOL	
5	%I0.3.4		EBOOL	
6	%I0.3.5		EBOOL	
7	%I0.3.6		EBOOL	
8	%I0.3.7		EBOOL	
9	%I0.3.8		EBOOL	
10	%I0.3.9		EBOOL	
11	%I0.3.10		EBOOL	
12	%I0.3.11		EBOOL	
13	%I0.3.12		EBOOL	
14	%I0.3.13		EBOOL	
15	%I0.3.14		EBOOL	
16	%I0.3.15		EBOOL	
17	%Q0.3.16		EBOOL	
18	%Q0.3.17		EBOOL	
19	%Q0.3.18		EBOOL	
20	%Q0.3.19		EBOOL	
21	%Q0.3.20		EBOOL	
22	%Q0.3.21		EBOOL	
23	%Q0.3.22		EBOOL	
24	%Q0.3.23		EBOOL	
25	%Q0.3.24		EBOOL	
26	%Q0.3.25		EBOOL	

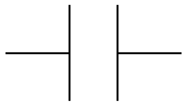
Ladder diagram Types of operands:

Bits	Description	Examples	Write access
Immediate values	0 or 1 (False or True)	0	_
Inputs/outputs	These bits are the "logic images" of the electrical states of the inputs/ outputs. They are stored in the data memory and updated each time the task in which they are configured is polled. **Note:** The unused input/output bits may not be used as internal bits.	%I23.5 %Q51,2	No Yes
Internal	The internal bits are used to store the intermediary states during execution of the program.	%M200	Yes
System	The system bits %S0 to %S127 monitor the correct operation of the PLC and the running of the application program.	%S10	According to i
Function blocks	The function block bits correspond to the outputs of the function blocks or DFB instance. These outputs may be either directly connected or used as an object.	%TM8.Q	No
Word extracts	With the PL7 software it is possible to extract one of the 16 bits of a word object.	%MW10:X5	According to the type of words
Grafcet steps and macro-steps	The Grafcet status bits of the steps, macro-steps and macro-step steps are used to recognize the Grafcet status of step i, of macro-step j or of step i of the macro-step j.	%X21 %X5.9	Yes Yes

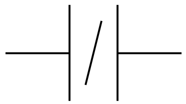
Ladder diagram

Basic Instructions *(input)*

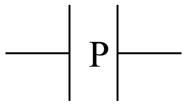
Load



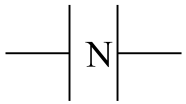
Normally open contact: contact is active (result is 1) when the control bit is 1.



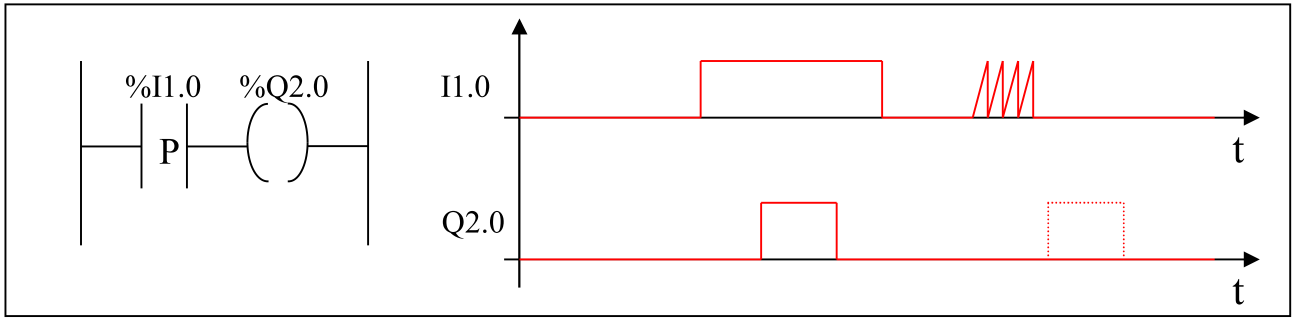
Normally closed contact: contact is active (result is 1) when the control bit is 0.



Contact in the **rising edge**: contact is active during a scan cycle where the control bit has a rising edge.



Contact in the **falling edge**: contact is active during a scan cycle where the control bit has a falling edge.



Ladder diagram

Basic Instructions

Load operands

Permitted operands The following table gives a list of the operands used for these instructions.

Ladder	Instruction list	Structured text	Operands
—| |—	LD	:=	%I,%Q,%M,%S,%BLK,%•:Xk, %Xi, (True and False in instruction list or structured text)
—|/|—	LDN	:=NOT	%I,%Q,%M,%S,%BLK,%•:Xk, %Xi, (True and False in instruction list or structured text)
—|P|—	LDR	:=RE	%I,%Q,%M
—|N|—	LDF	:=FE	%I,%Q,%M

Ladder diagram

Basic Instructions *(output)*

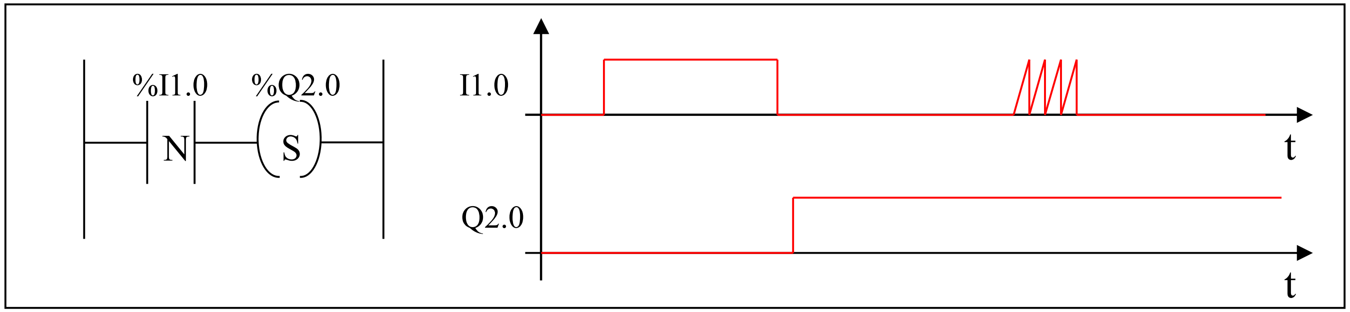
Store

—( )— The result of the logic function activates the coil.

—(/)— The inverse result of the logic function activates the coil.

—(S)— The result of the logic function energizes the relay (sets the latch).

—(R)— The result of the logic function de-energizes the relay (resets the latch)..



Ladder diagram

Basic Instructions

Store operands

Permitted operands The following table gives a list of the operands used for these instructions

Language data	Instruction list	Structured text	Operands
—( )—	ST	:=	%I,%Q,%M,%S,%•:Xk
—(/)—	STN	:=NOT	%I,%Q,%M,%S,%•:Xk
—(S)—	S	SET	%I,%Q,%M,%S,%•:Xk,%Xi Only in the preliminary processing.
—(R)—	R	RESET	%I,%Q,%M,%S,%•:Xk,%Xi Only in the preliminary processing.

Ladder diagram

Allen Bradley notation

Relays with *latch* and *unlatch*

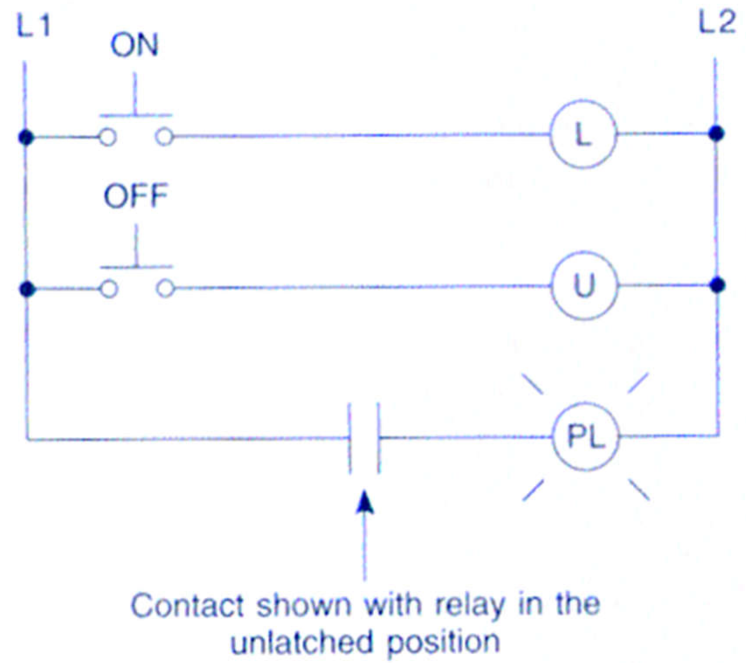


Fig. 6-50

Schematic of electromagnetic latching relay.

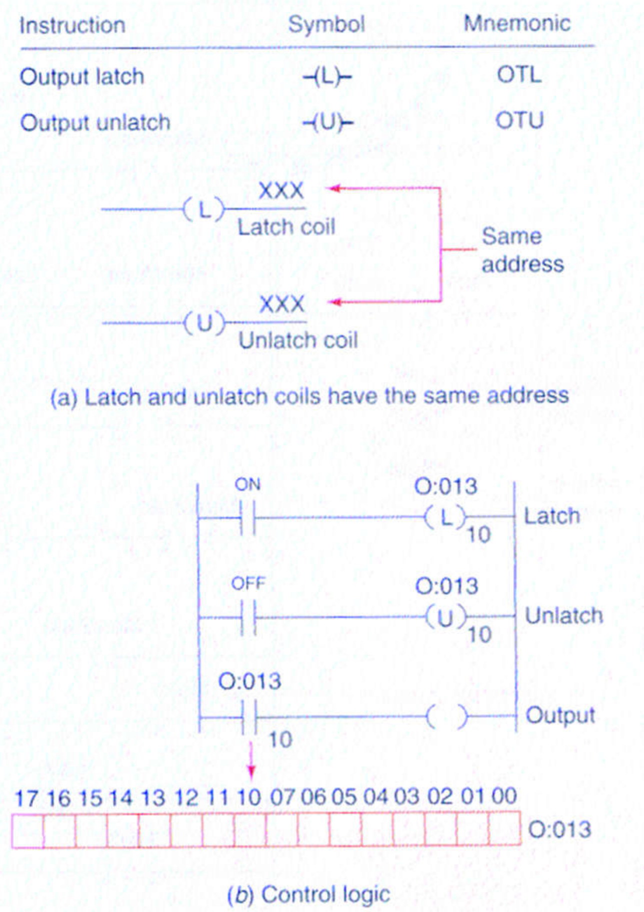
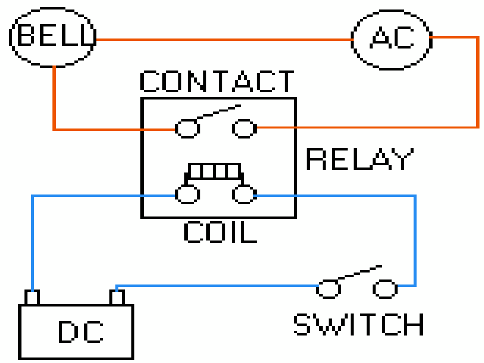


Fig. 6-51

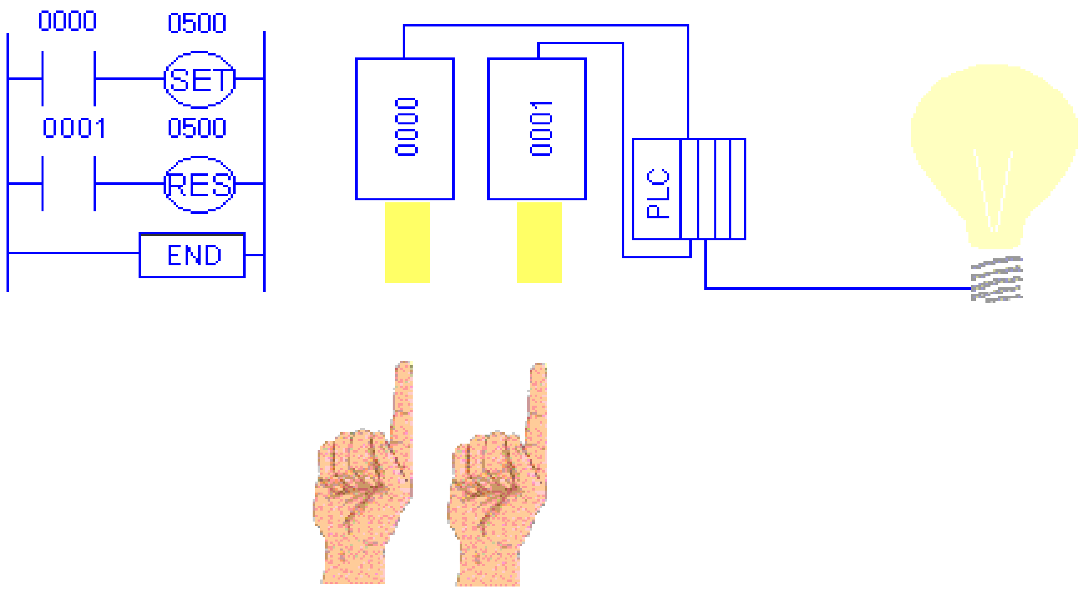
OUTPUT LATCH and OUTPUT UNLATCH instructions.

Ladder diagram



Relay-type instructions

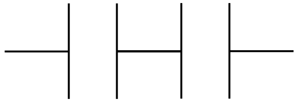
Example:



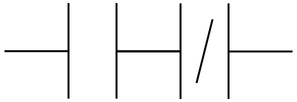
Ladder diagram

Basic Instructions

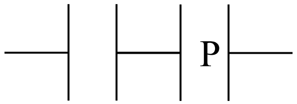
AND



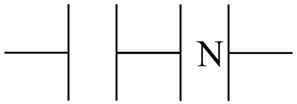
AND of the operand with the result of the previous logical operation.



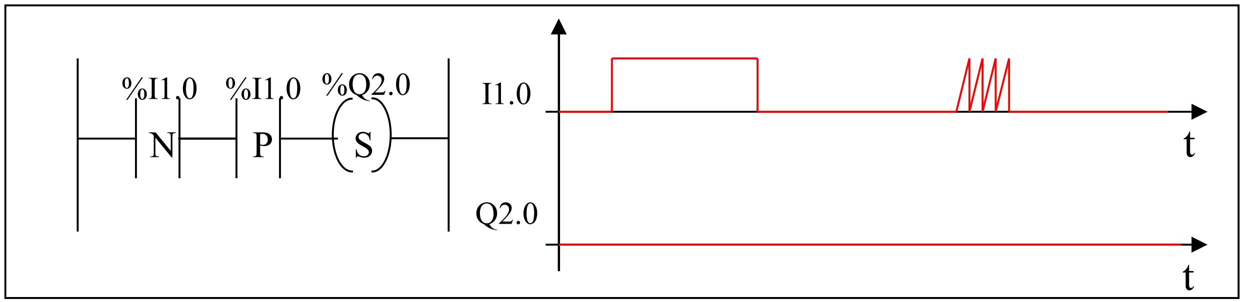
AND of the inverted operand with the result of the previous logical operation.



AND of the rising edge with the result of the previous logical operation.

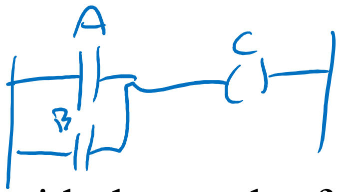


AND of the falling edge with the result of the previous logical operation.



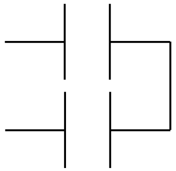
Ladder diagram

Basic Instructions

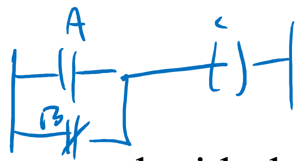


$C = A + B$

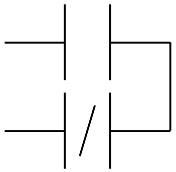
OR



OR of the operand with the result of the previous logical operation.

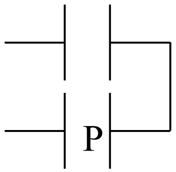


$C = A + \overline{B}$



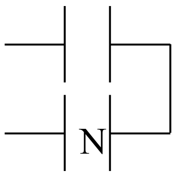
OR of the inverted operand with the result of the previous logical operation.

$C = A + B\uparrow$



OR of the rising edge with the result of the previous logical operation.

$C = A + B\downarrow$

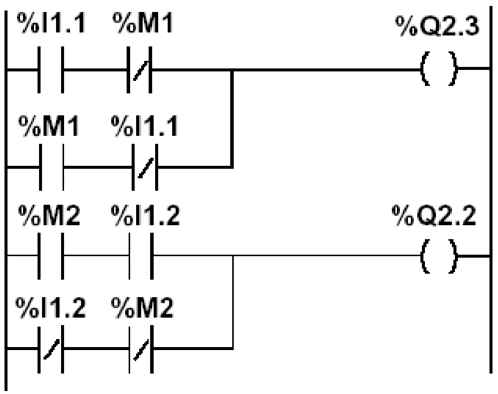


OR of the falling edge with the result of the previous logical operation.

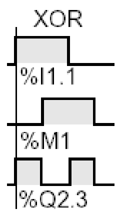
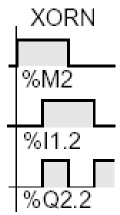
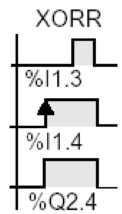
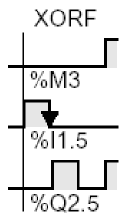
Ladder diagram

Basic Instructions

XOR

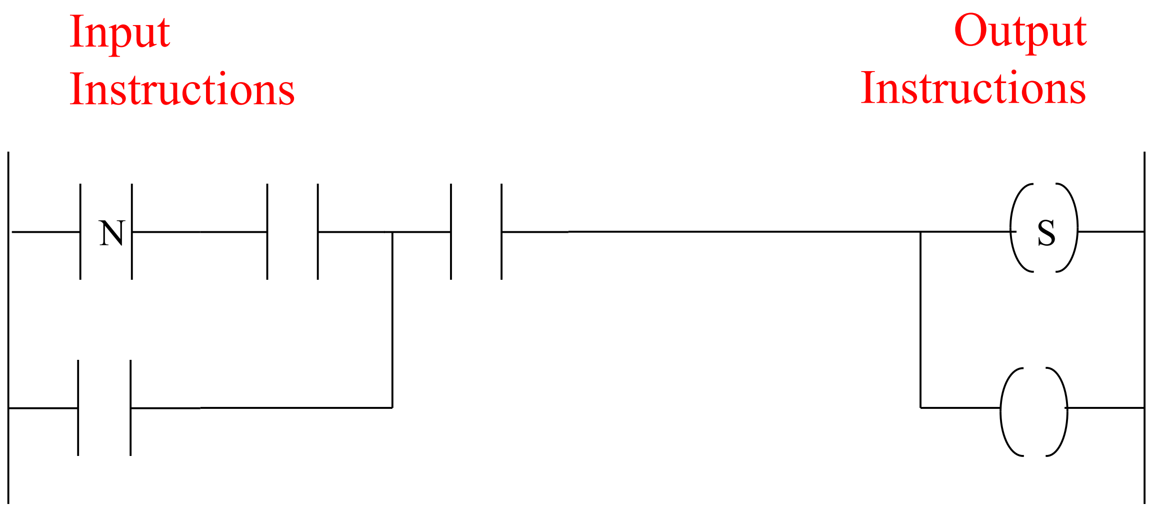


%Q2.3 := %I1.1 XOR %M1;
%Q2.2 := NOT(%M2 XOR %I1.2);
%Q2.2 := %M2 XOR NOT(%I1.2);

Instruction list	Structured text	Description	Timing diagram
XOR	XOR	OR Exclusive between the operand and the previous instruction's Boolean result	
XORN	XOR (NOT...)	OR Exclusive between the operand inverse and the previous instruction's Boolean result	
XORR	XOR (RE...)	OR Exclusive between the operand's rising edge and the previous instruction's Boolean result	
XORF	XOR (FE...)	OR Exclusive between the operand's falling edge and the previous instruction's Boolean result.	

Ladder diagram

Ladder assembling



The outputs that have a TRUE logical value, evaluated from the left to right and from the top to the bottom, are **energized .**

[Schneider, Micro PLCs]

Ladder diagram

Example:
Latch / Sealing, Feedback

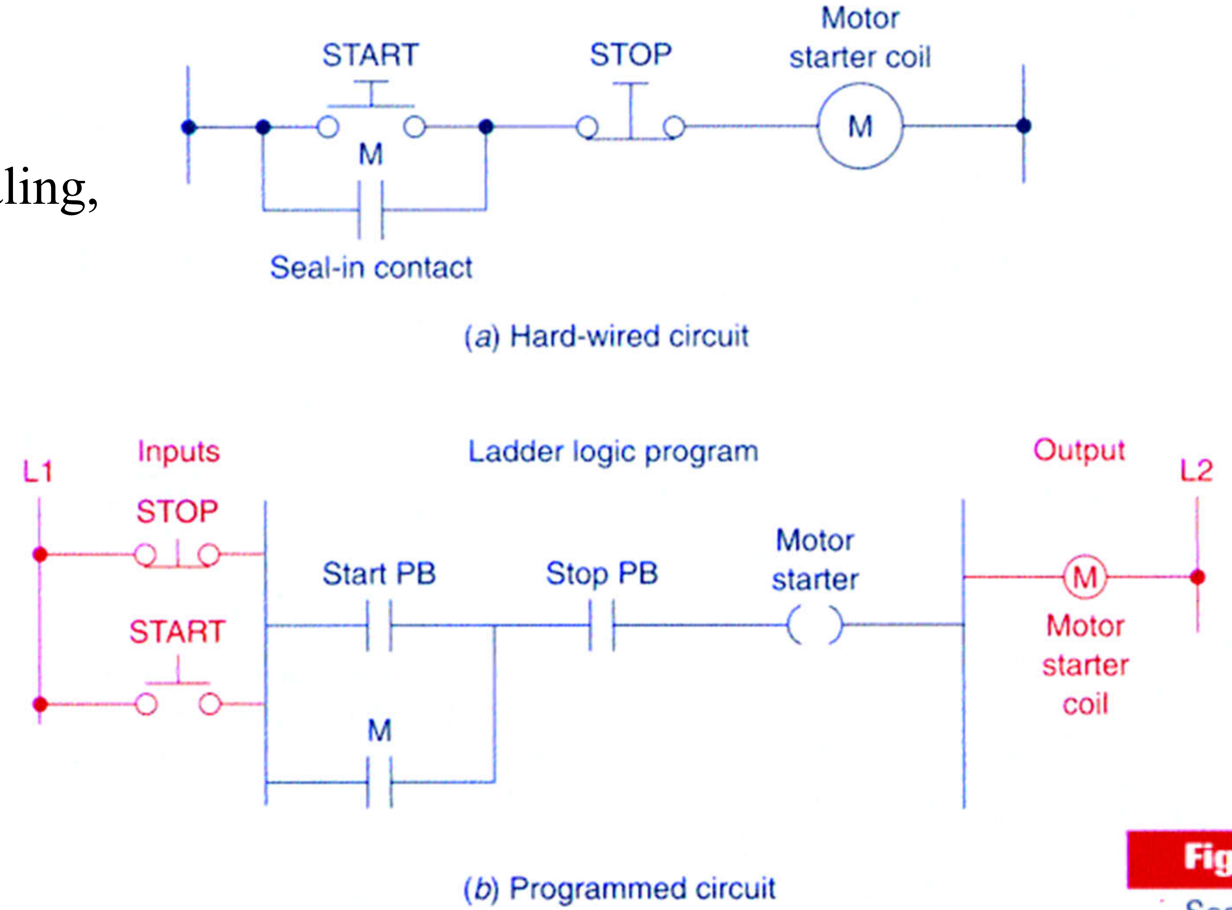
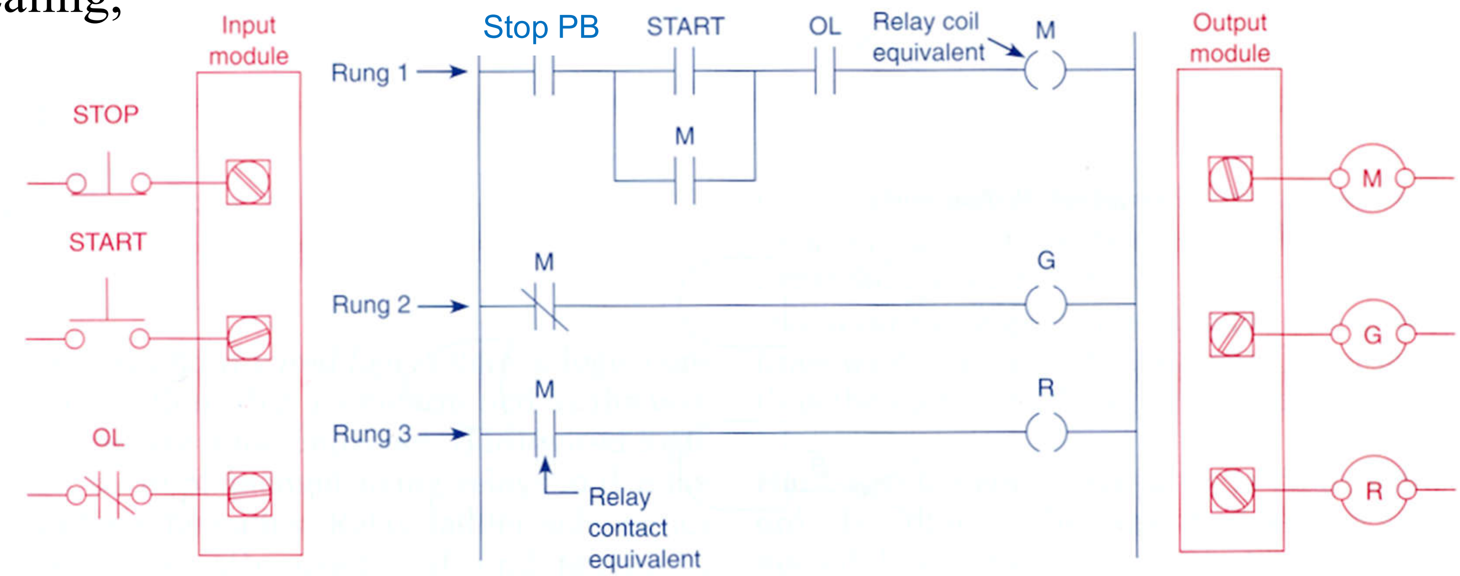


Fig. 6-48
Seal-in circuit.

The ***normally closed*** *push button* ***STOP*** *drives the normally open contact* ***Stop PB***

Ladder diagram

Example:
Latch / Sealing,
Feedback



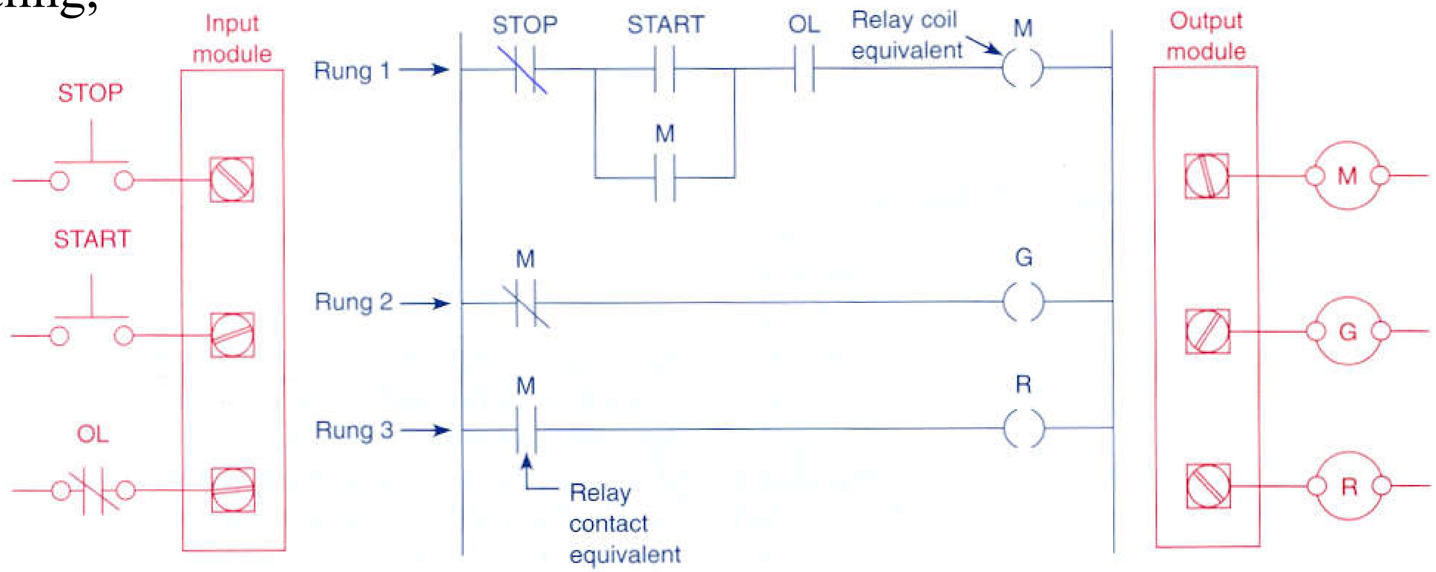
The ***normally closed*** *push button* ***STOP*** *drives the normally open contact* ***Stop PB***

Ladder diagram

Example:

Latch / Sealing,

Feedback



***STOP** button **normally open** implies **inverting that input** in the ladder diagram.*

Ladder diagram

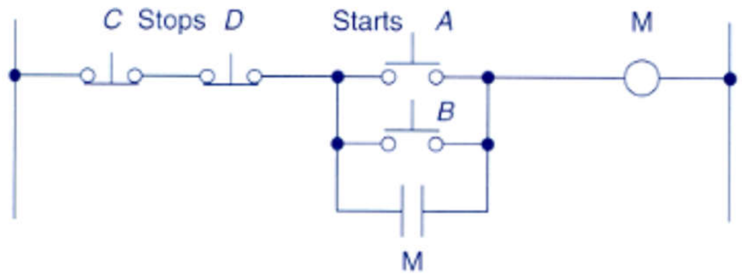
Example:
Latch / Sealing,
Feedback

Example 4-9

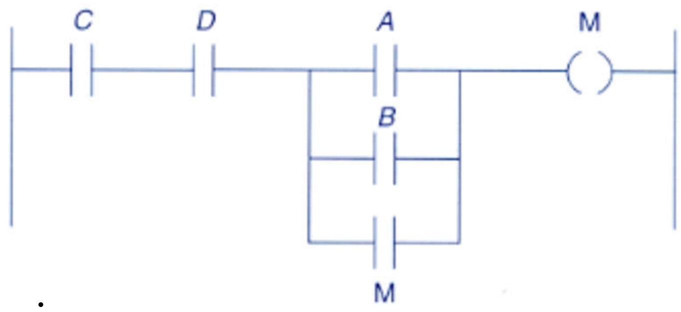
A motor control circuit with two stop buttons:

- When the start button is depressed, the motor runs.
- By sealing, it continues to run when the start button is released.
- The stop buttons stop the motor when they are depressed.

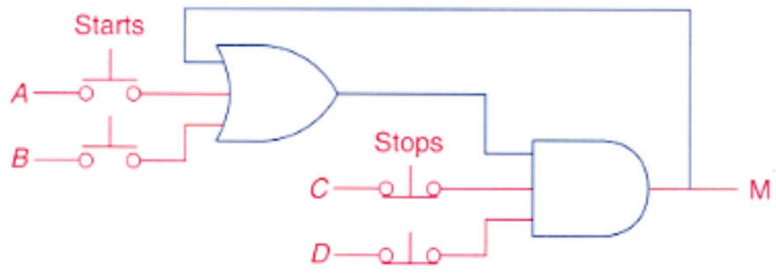
Relay Schematic



Ladder logic program



Gate logic



Ladder diagram

General case of Inputs and Outputs in **parallel**, with **derivations**

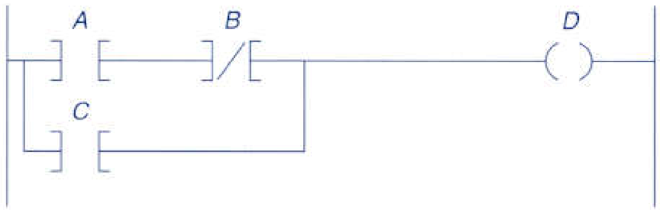


Fig. 5-21
Parallel input branching.

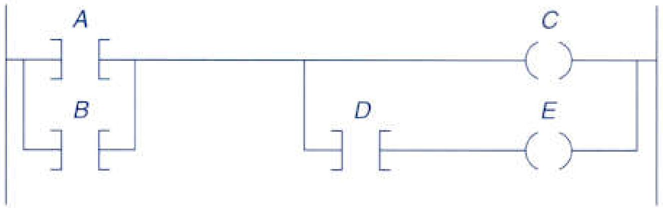


Fig. 5-23
Parallel output branching with conditions.

Fig. 5-22
Parallel output branching.

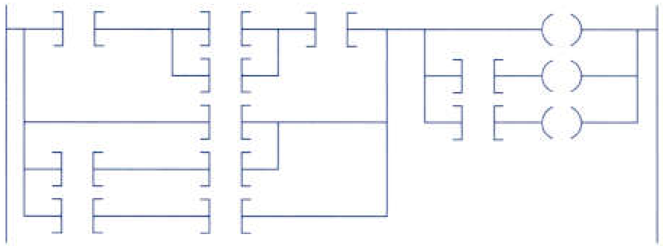


Fig. 5-24
Nested input and output branches.

Note: it is important to study the **constraints** and **potentialities** of the development tools.

Ladder diagram

Imbricated (nested) contacts and **alternative** solution

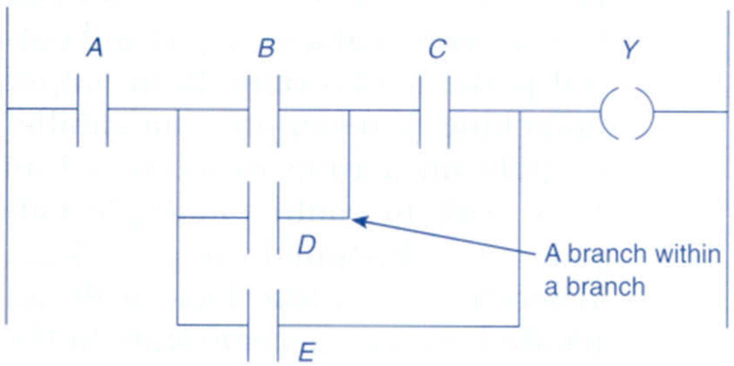


Fig. 5-25
Nested contact program.

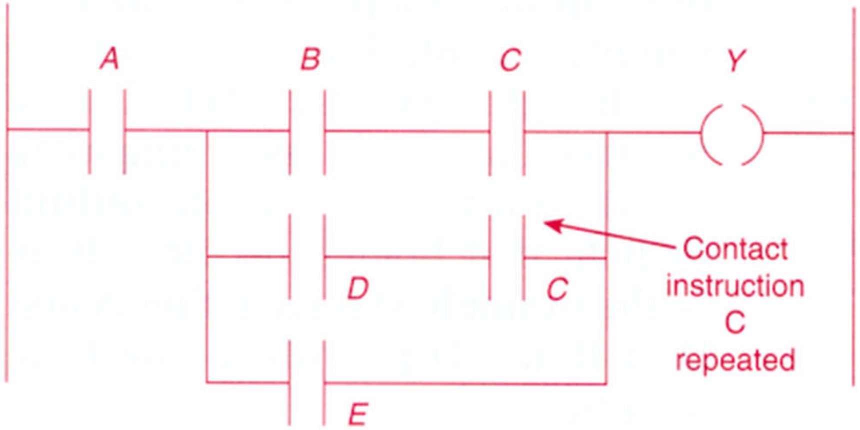


Fig. 5-26
Program required to eliminate nested contact.

Ladder diagram

Contacts in the **vertical** and **alternative** solution

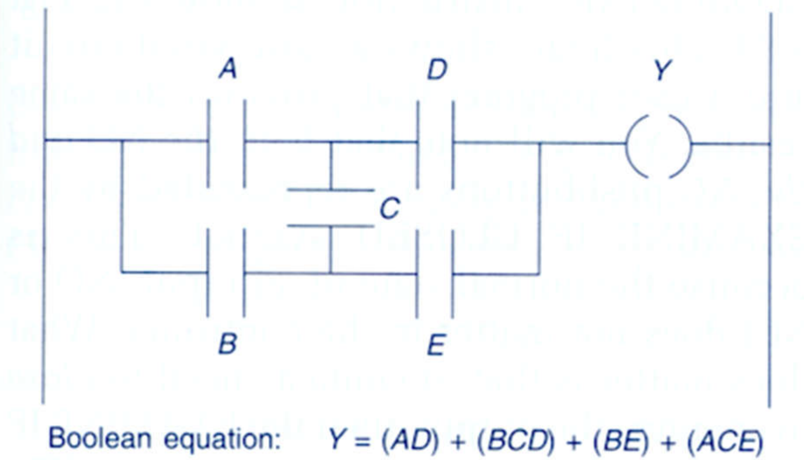


Fig. 5-28

Program with vertical contact

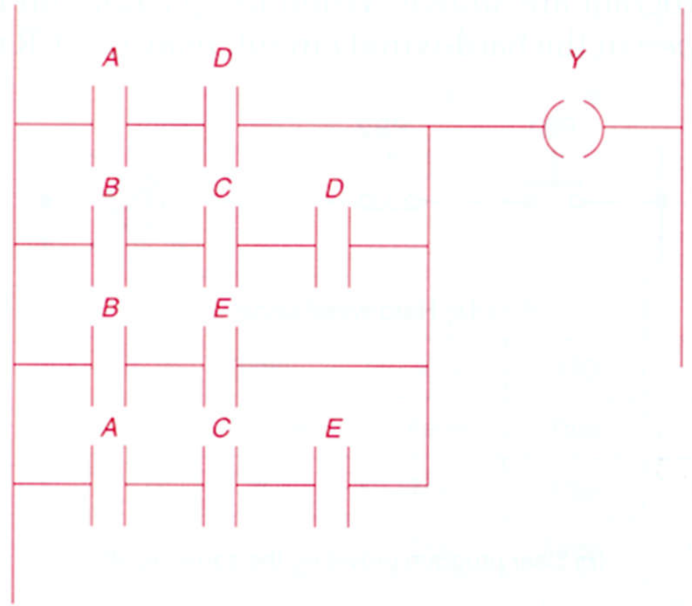


Fig. 5-29

Reprogrammed to eliminate vertical contact.

Ladder diagram

Contacts in the **vertical** and **alternative** solution

Another example:

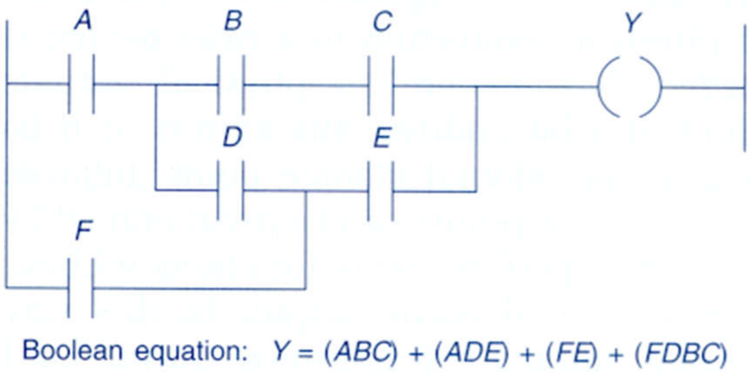


Fig. 5-30
Original circuit.

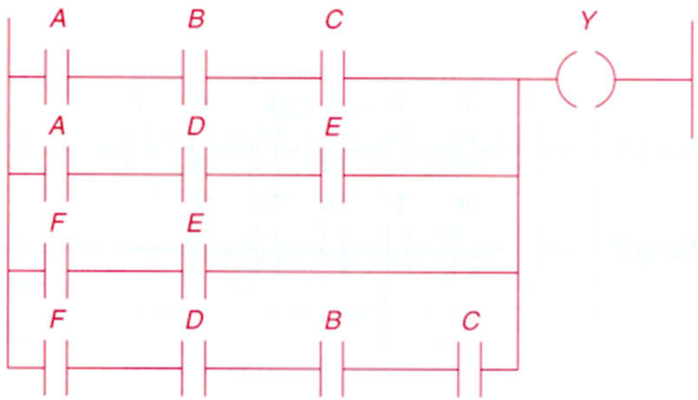
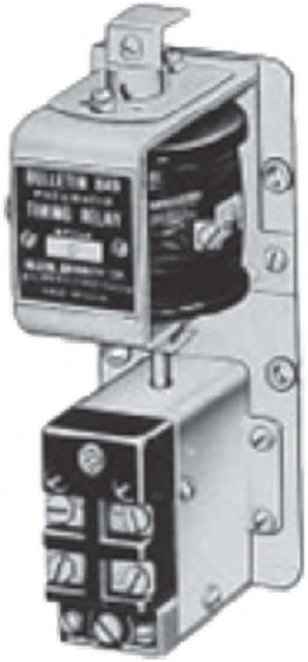


Fig. 5-31
Reprogrammed circuit.

Solves the problem of disallowed right to left scanning (FDBC in fig5.30).

Ladder diagram *Temporized Relays or Timers*

Solid-state timing relay

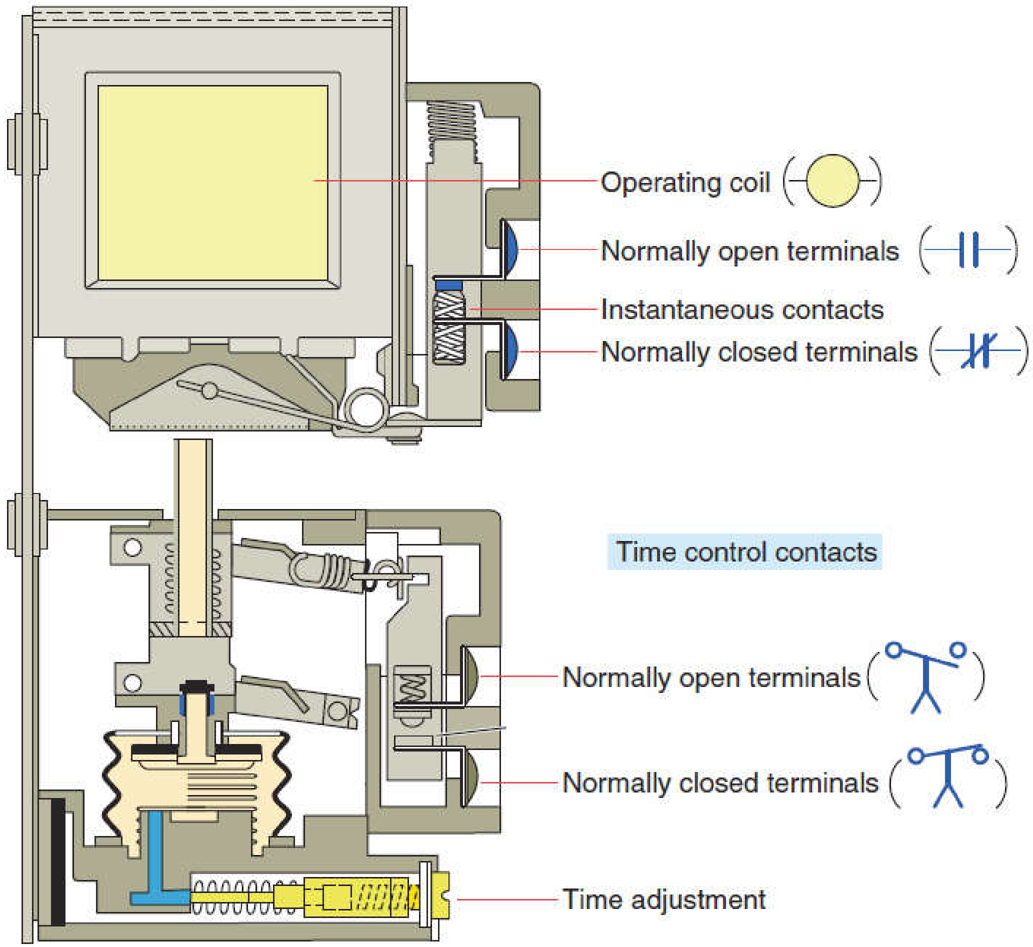


Pneumatic timing relay

Plug-in timing relay

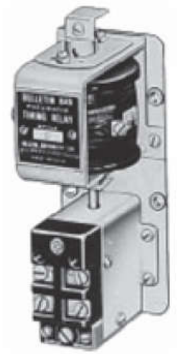
Ladder diagram *Temporized Relays or Timers (pneumatic)*

Pneumatic timing relay

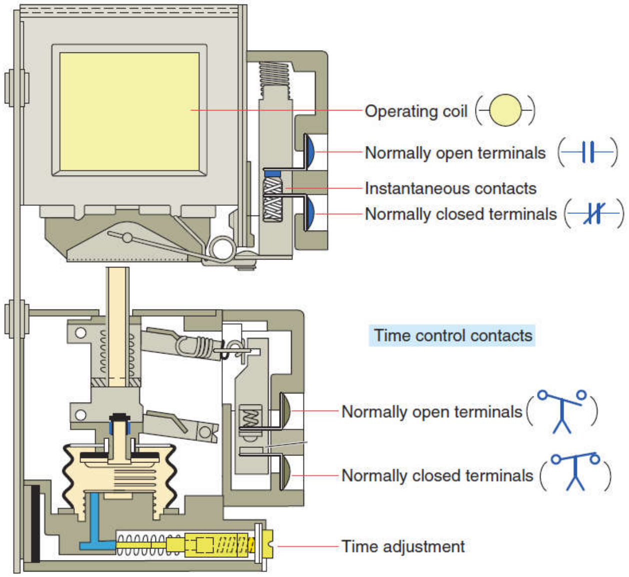


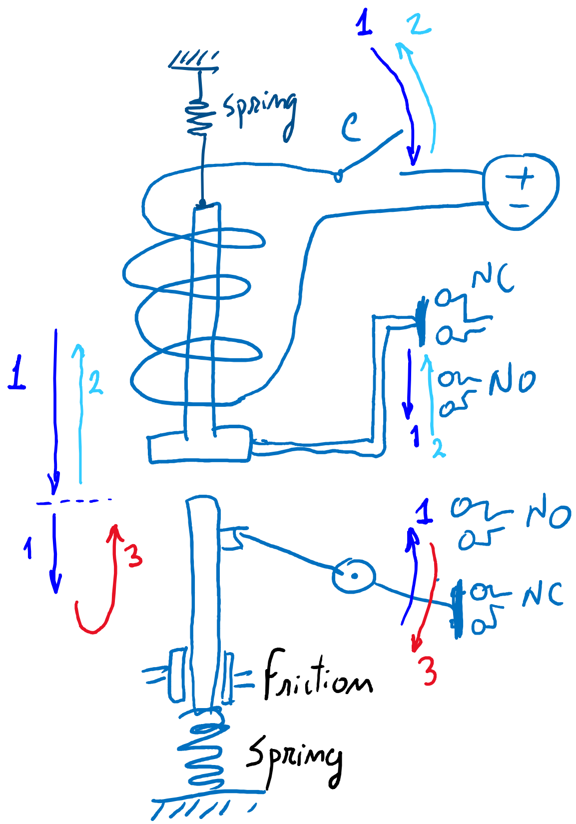
The instantaneous contacts change state as soon as the timer coil is powered.
The delayed contacts change state at the end of the time delay.

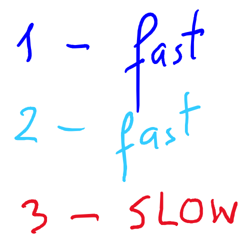
Ladder diagram *Temporized Relays or Timers (pneumatic)*



Pneumatic timing relay







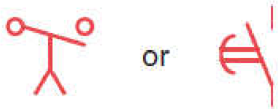
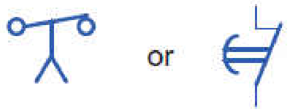
Input

Output
NOTC
NCTO

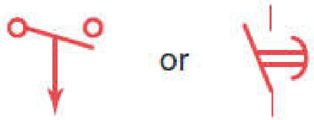
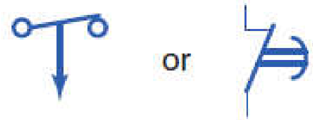
The **instantaneous** **contacts change state as soon as the timer coil is powered.**
The **delayed** **contacts change state at the end of the time delay.**

Ladder diagram *Temporized Relays or Timers*

On-delay, provides time delay when the relay coil is energized.

On-delay symbols	
	
Normally open, timed closed contact (NOTC).	Normally closed, timed open contact (NCTO).
Contact is open when relay coil is de-energized.	Contact is closed when relay coil is de-energized.
When relay is energized, there is a time delay in closing.	When relay is energized, there is a time delay in opening.

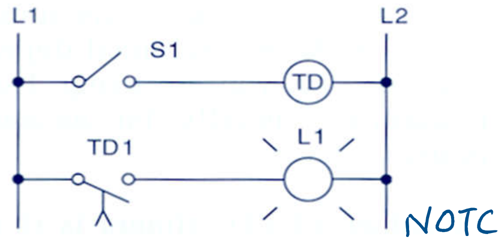
Off-delay, provides time delay when the relay coil is de-energized.

Off-delay symbols	
	
Normally open, timed open contact (NOTO).	Normally closed, timed closed contact (NCTC).
Contact is normally open when relay coil is de-energized.	Contact is normally closed when relay coil is de-energized.
When relay coil is energized, contact closes instantly.	When relay coil is energized, contact opens instantly.
When relay coil is de-energized, there is a time delay before the contact opens.	When relay coil is de-energized, there is a time delay before the contact closes.

Tables: Relay *symbols* used for timed contacts.

Ladder diagram *Temporized Relays or Timers*

Timer On-delay (TON)



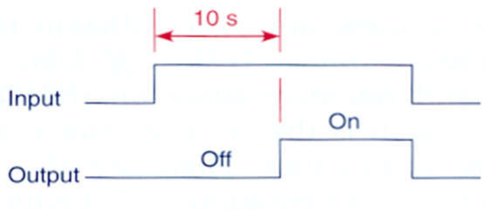
Sequence of operation:
S1 open, TD de-energized, TD1 open, L1 off.

S1 closes, TD energizes, timing period starts, TD1 is still open, L1 is still off.

After 10 s, TD1 closes, L1 is switched on.

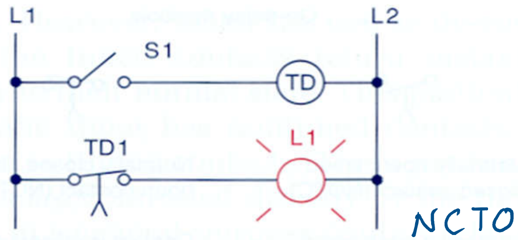
S1 is opened, TD de-energizes, TD1 opens instantly, L1 is switched off.

(*a*)



(*b*)

Fig. 7-3
On-delay timer circuit (NOTC contact). (a) Operation. (b) Timing diagram.



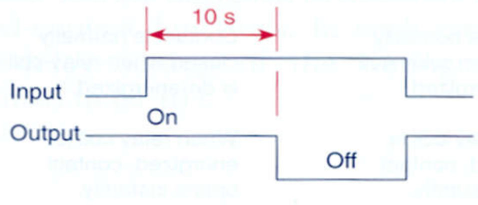
Sequence of operation:
S1 open, TD de-energized, TD1 closed, L1 on.

S1 closes, TD energizes, timing period starts, TD1 is still closed, L1 is still on.

After 10 s, TD1 opens, L1 is switched off.

S1 is opened, TD de-energizes, TD1 closes instantly, L1 is switched on.

(*a*)



(*b*)

Fig. 7-4
On-delay timer circuit (NCTO contact). (a) Operation. (b) Timing diagram.

Ladder diagram *Temporized Relays or Timers*

Timer Off-delay (TOF)

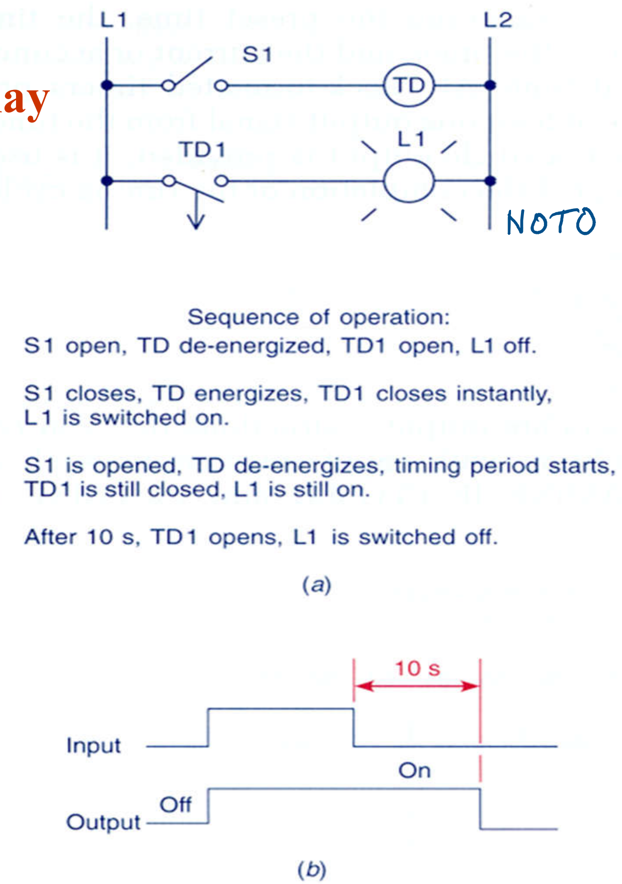


Fig. 7-5
Off-delay timer circuit (NOTO contact). (a) Operation. (b) Timing diagram.

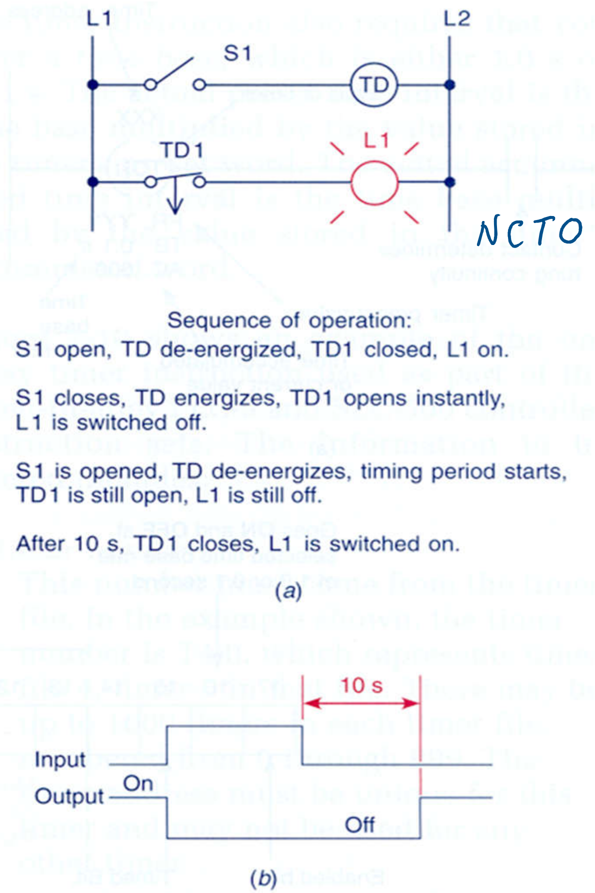
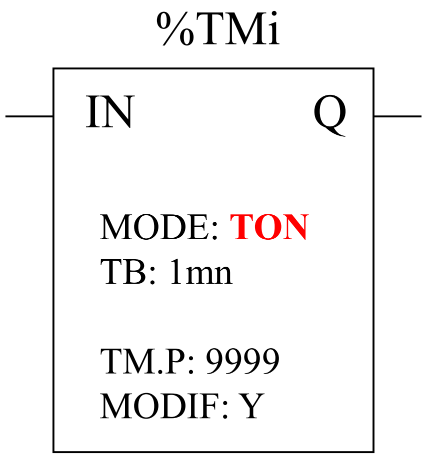


Fig. 7-6
Off-delay timer circuit (NCTC contact). (a) Operation. (b) Timing diagram.

Ladder diagram

Temporized Relays

or Timers (PLC)



Characteristics:

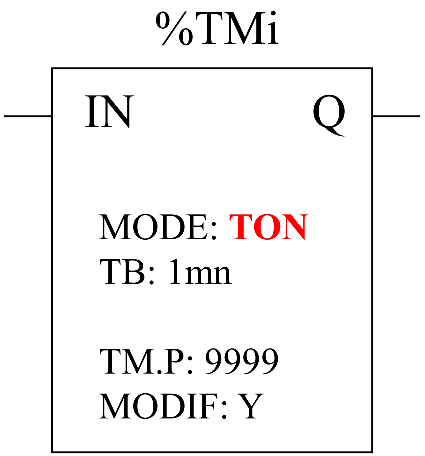
Identifier: %TMi	0..63 in the TSX37	
Input:	IN	to activate
Mode:	**TON** **TOF** **TP**	**Timer On delay** **Timer Off delay** **Monostable**
Time basis:	TB	1mn (def.), 1s, 100ms, 10ms
Programmed value:	%TMi.P	0...9999 (def.) period=TB*TMi.P
Actual value:	%TMi.V	0...TMi.P (can be read or tested)
Modifiable:	Y/N	can be modified from the console

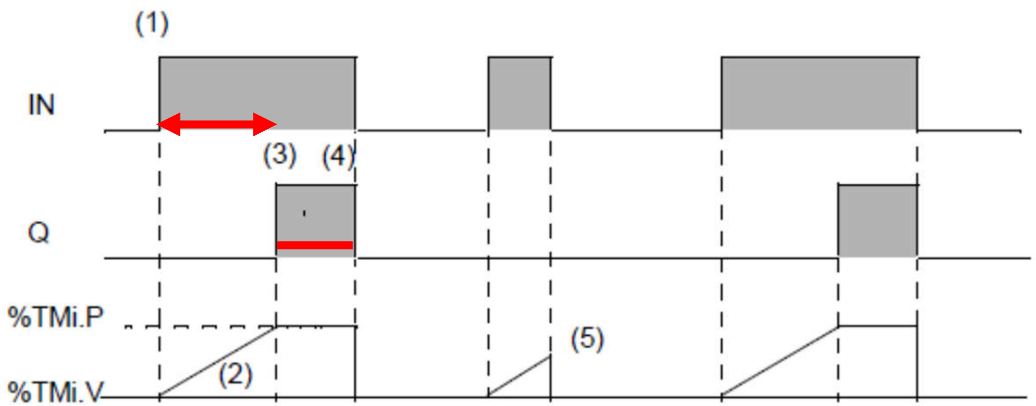
Ladder diagram

TON mode

Temporized Relays

or Timers (PLC)





Phase	Description
1	The timer is started with a rising edge on the IN input
2	The current value %TMi.V of the timer increases from 0 to %TMi.P by one unit at each pulse of the time base TB
3	The %TMi.Q output bit moves to 1 when the current value has reached %TMi.P
4	The %TMi.Q output bit stays at 1 while the IN input is at 1.
5	When the IN input is at 0, the timer is stopped even if it is still running: %TMi.V takes the value 0.

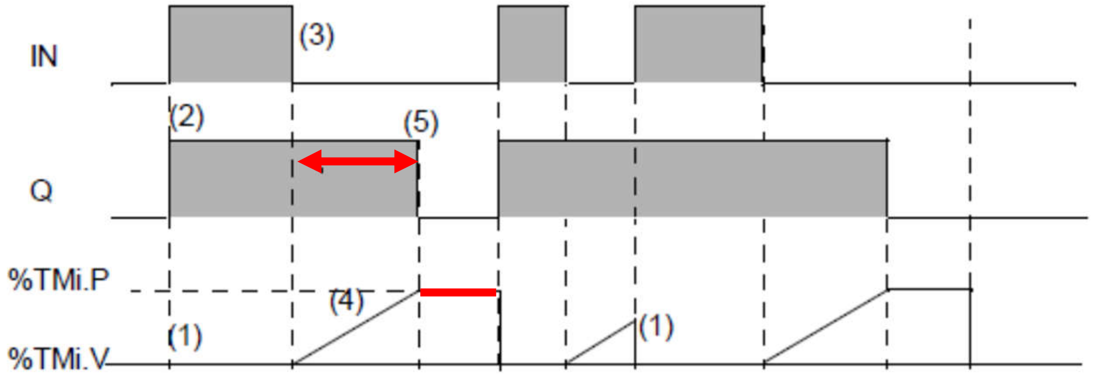
App. example: start ringing the alarm if N sec after door open there is no disarm of the alarm.

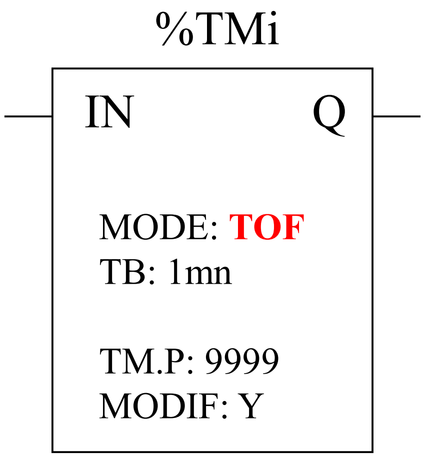
Ladder diagram

TOF mode

Temporized Relays

or Timers (PLC)





Phase	Description
1	The current value %TMi.V takes 0, on a rising edge of the IN input (even if the timer is running)
2	The %TMi.Q output bit moves to 1.
3	The timer is started with a falling edge on the IN input.
4	The current value %TMi.P increases to %TMi.P by one unit at each pulse of the time base TB.
5	The %TMi.Q output bit returns to 0 when the current value has reached %TMi.P

App. example: turn off stairways lights after N sec the lights' button has been released.

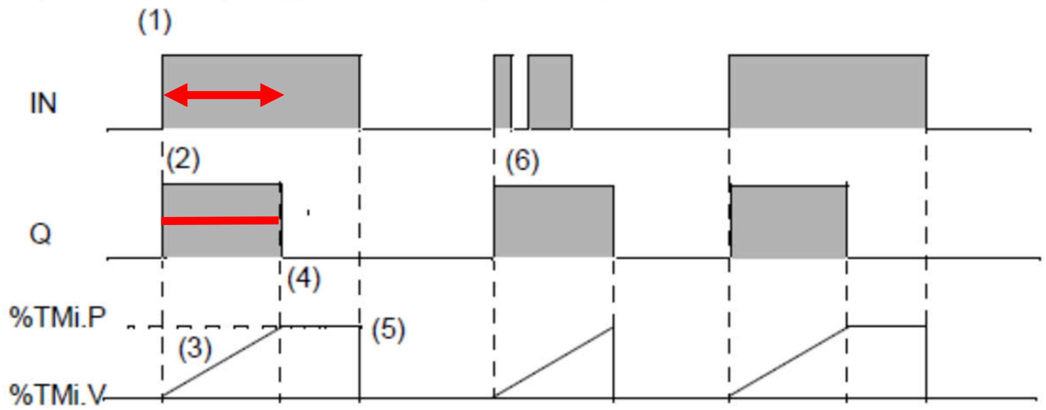
Ladder diagram

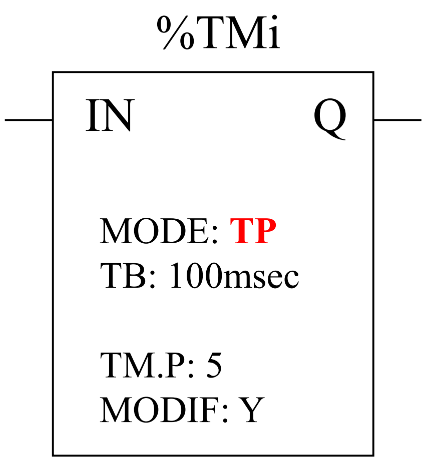
TP mode

Temporized Relays

or Timers (PLC)

Works as a monostable or as a pulse generator (with pre-programmed period)



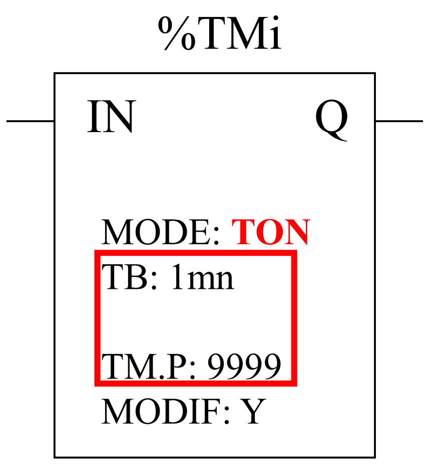


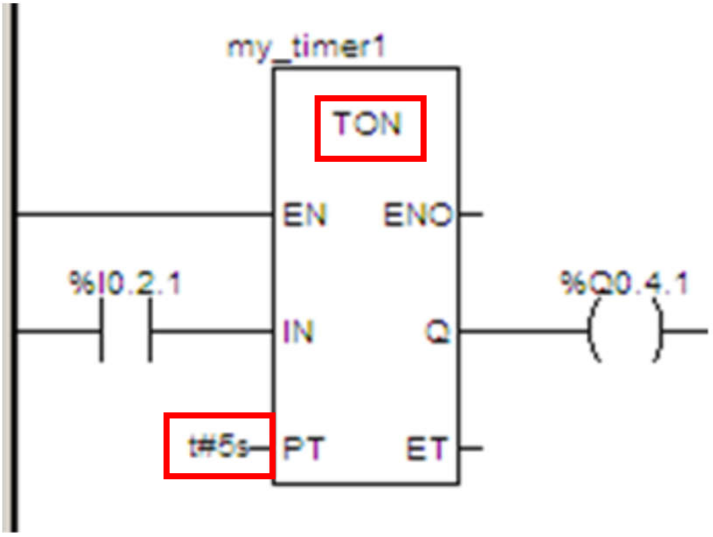
Phase	Description
1	The timer is started with a rising edge on the IN input
2	The %TMi.Q output bit moves to 1.
3	The current value %TMi.V of the timer increases from 0 to %TMi.P by one unit at each pulse of the time base TB
4	The %TMi.Q output bit returns to 0 when the current value has reached %TMi.P.
5	When the IN input and the %TMi.Q output are at 0, %TMi.V takes the value 0.
6	This monostable cannot be reactivated.

App. example: positive input edge give a controlled (fixed) duration pulse to start a motor.

Ladder diagram

Timers in PL7 vs Unity (Schneider)



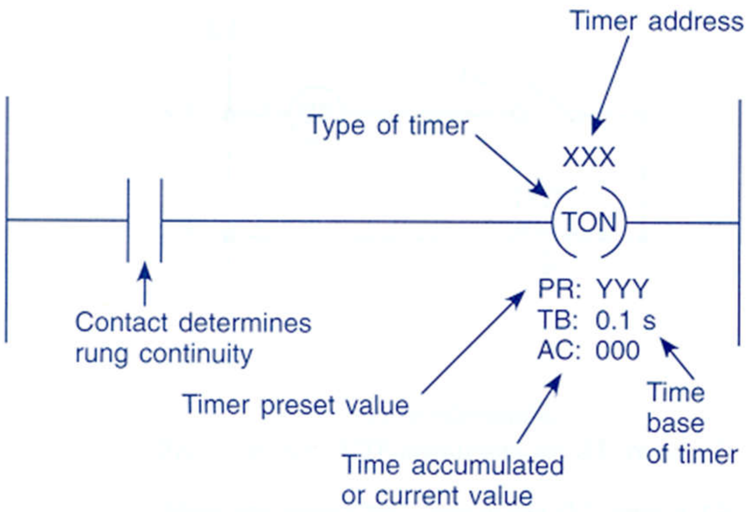


Input EN and output ENO are facultative

Ladder diagram

Timers in the *Allen-Bradley* PLC-5

Two alternative representations



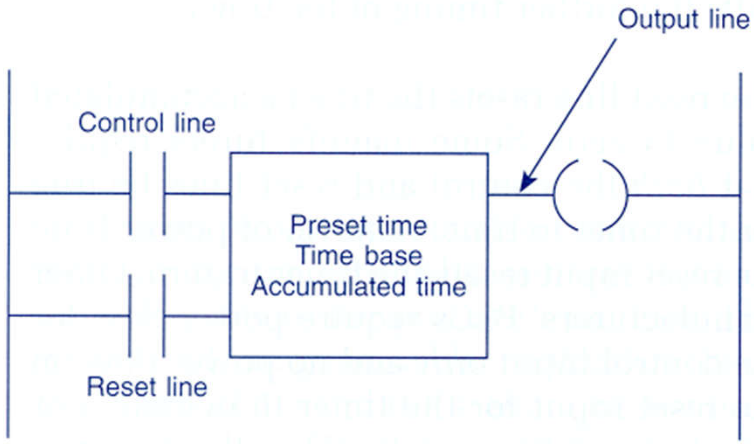
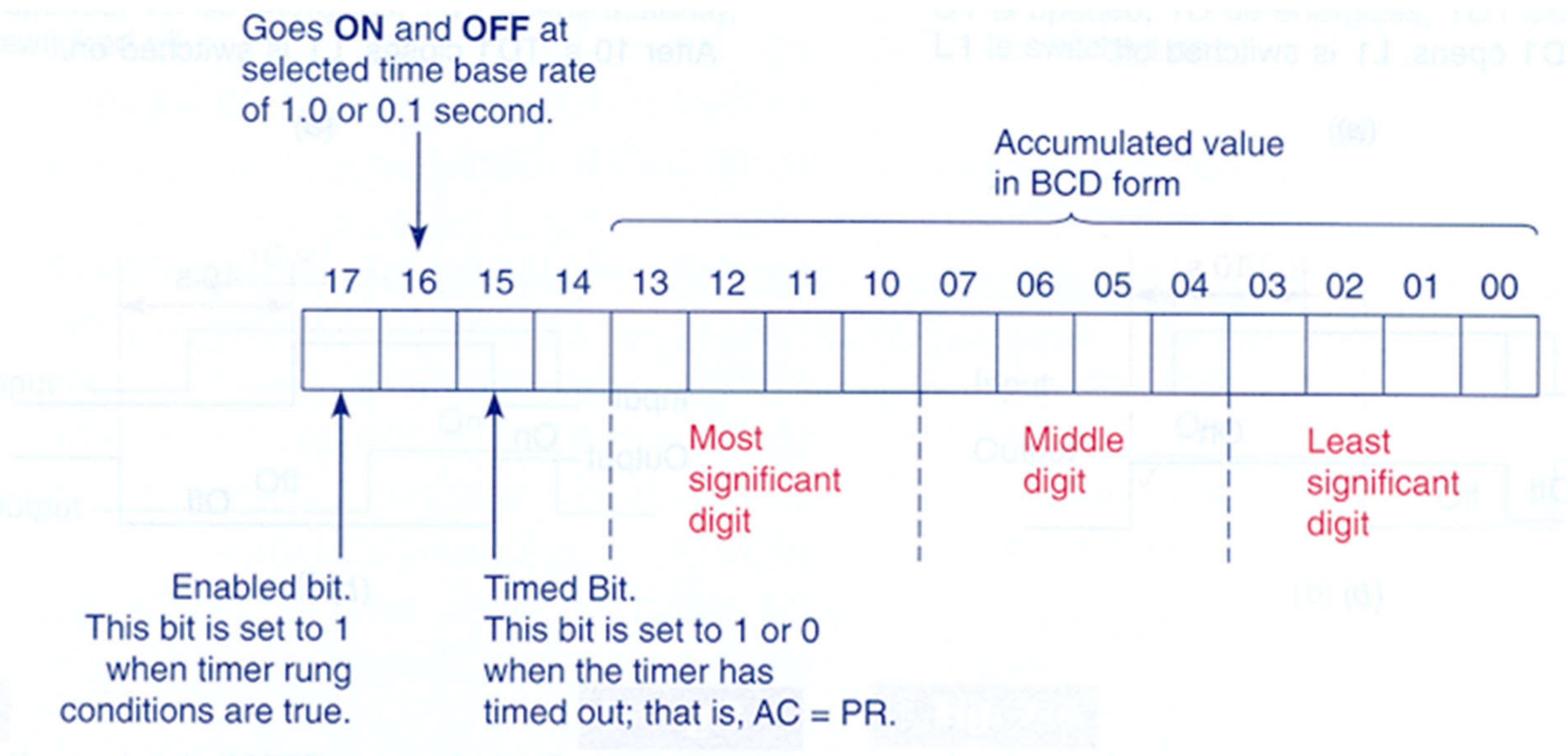


Fig. 7-8
Block-formatted timer instruction.

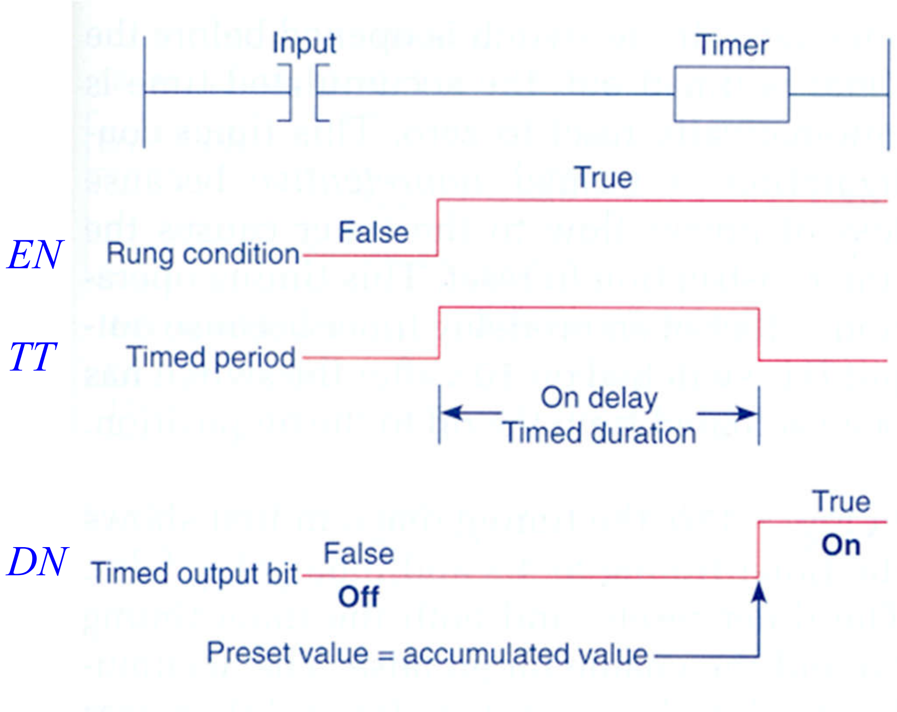
Ladder diagram

Timers implementation in the *Allen-Bradley* PLC-5:



Ladder diagram

Timers operation in the *Allen-Bradley* PLC-5



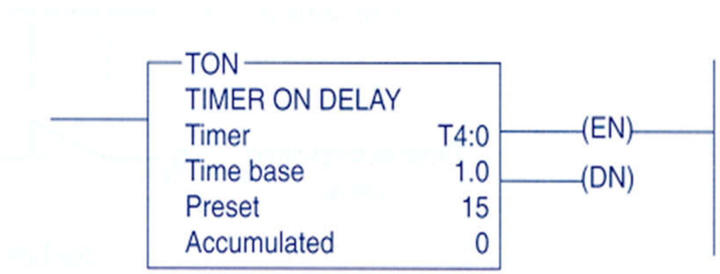


Fig. 7-10
On-delay timer instruction.

EN = Enable Bit *TT = Timer-Timing Bit* *DN = Done Bit*

Ladder diagram

Example of *timer on-delay*

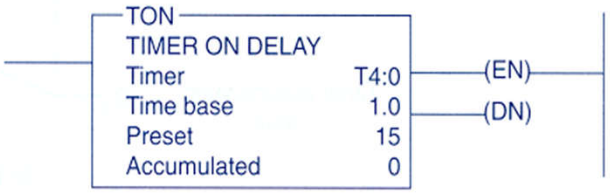


Fig. 7-10
On-delay timer instruction.

Timer element

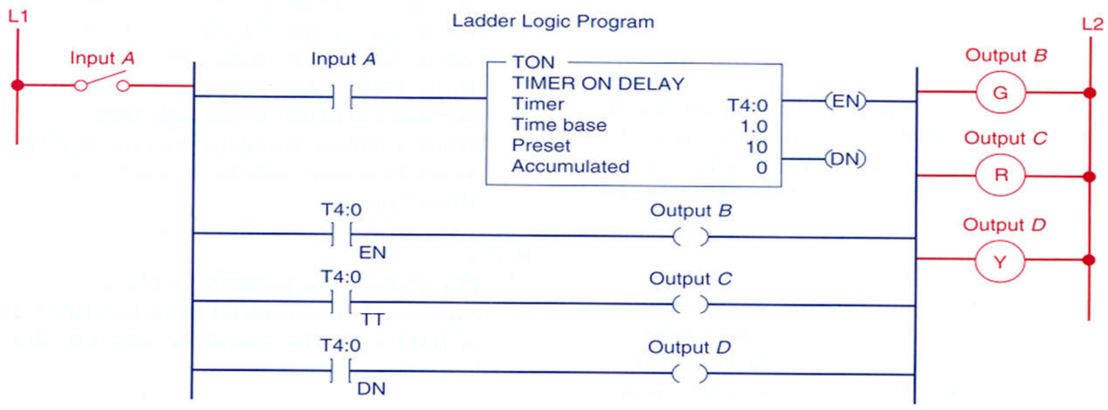
Bits 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0		Word
EN TT DN	Internal use	0
Preset value PRE		1
Accumulated value ACC		2

Addressable bits
- EN = Bit 15 enable
- TT = Bit 14 timer timing
- DN = Bit 13 done

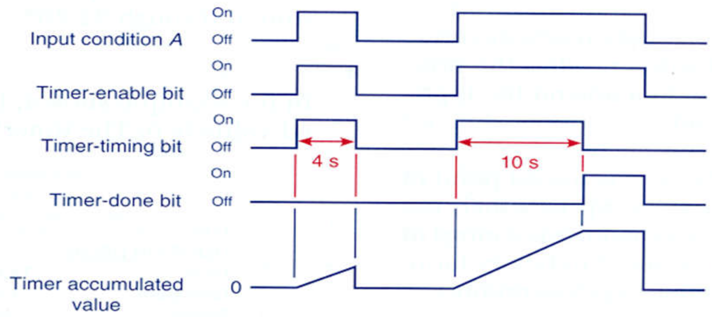
Addressable words
- PRE = Preset value
- ACC = Accumulated value

(*c*) Timers are 3-word elements. Word 0 is the control word, word 1 stores the preset value, and word 2 stores the accumulated value (Allen-Bradley PLC-5 and SLC-500 format).

Fig. 7-11 (continued)
On-delay timer.



(*a*) Ladder diagram



(*b*) Timing diagram

Fig. 7-11
On-delay timer.

Ladder diagram

Example of a *timer on-delay that sets an output after a count-down*

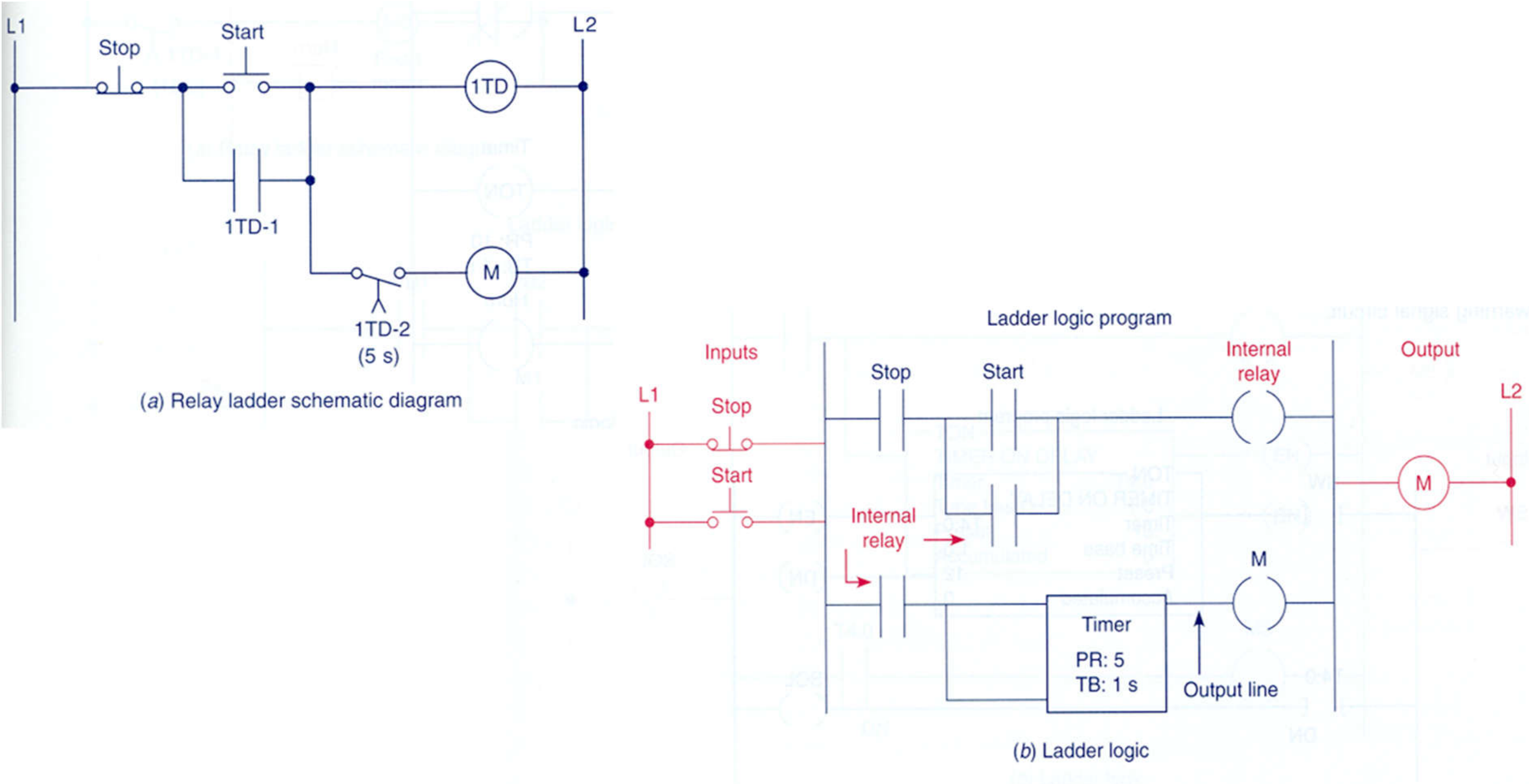


Fig. 7-12
On-delay timer with instantaneous output programming.

Ladder diagram

Example of *timer on-delay*

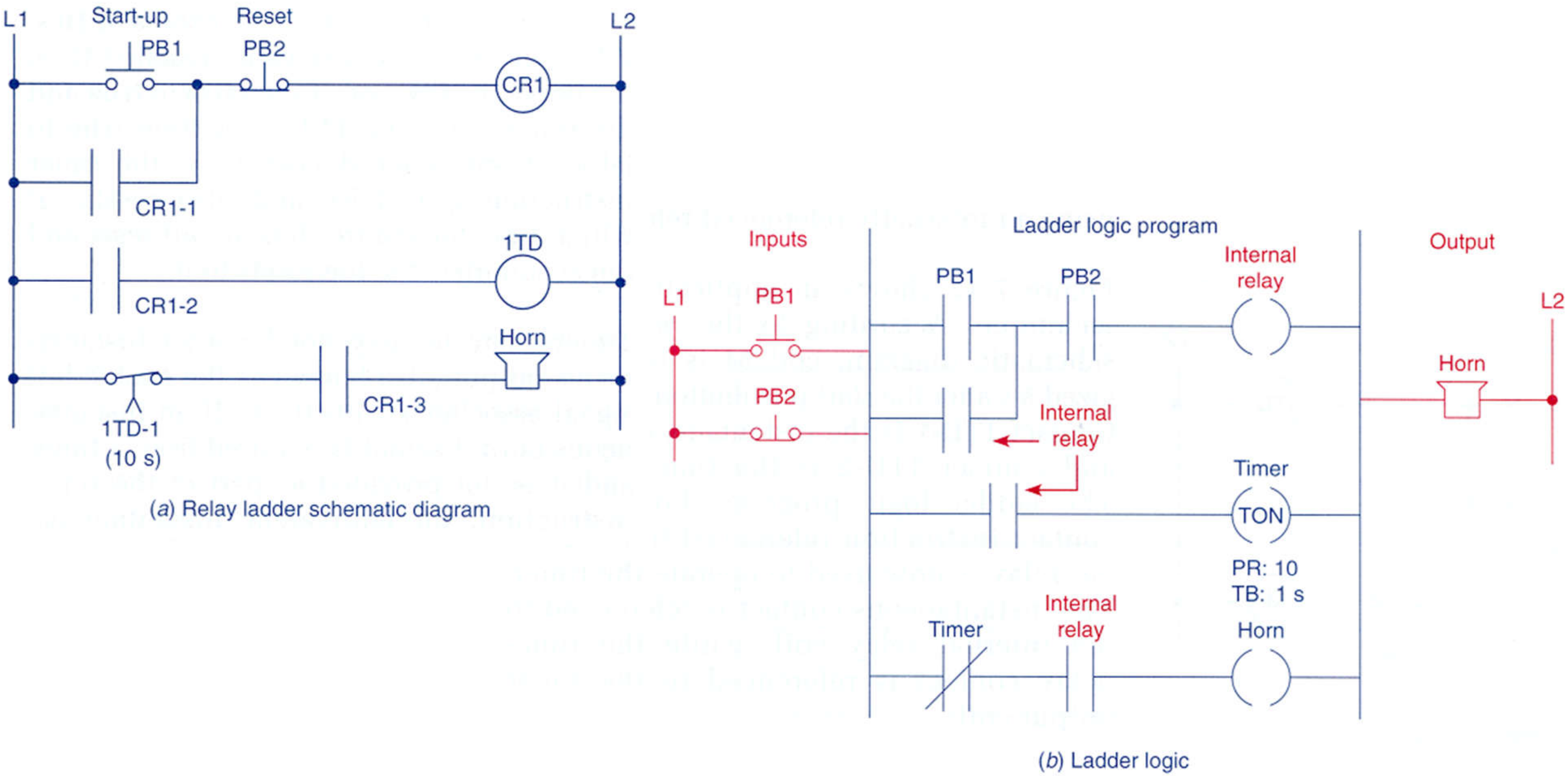


Fig. 7-13
Starting-up warning signal circuit.

Ladder diagram

Example of *timer on-delay*

Coil is energized if the switch remains closed for 12 seconds

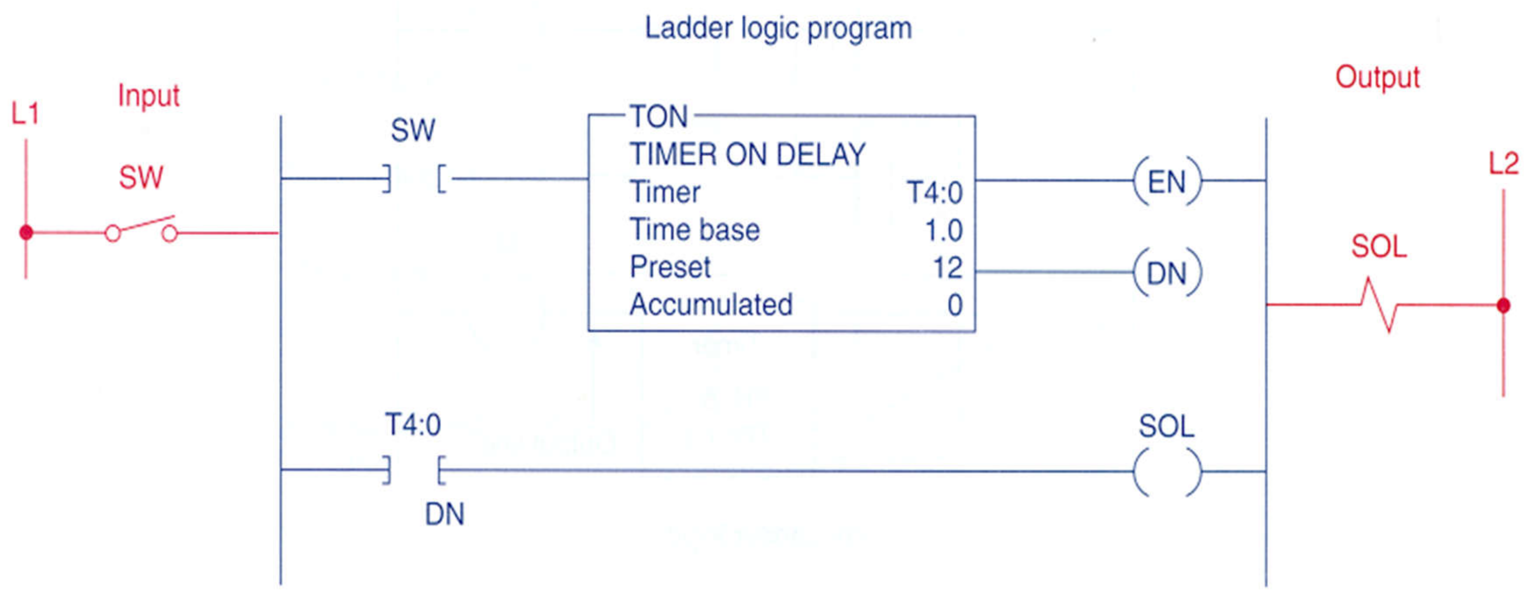


Fig. 7-14
Solenoid valve timed closed.

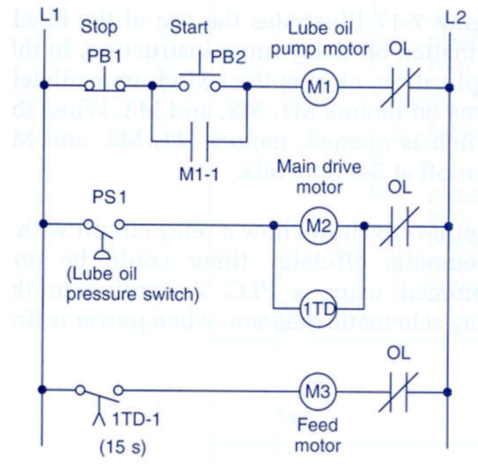
Ladder diagram

Example of *timer on-delay*

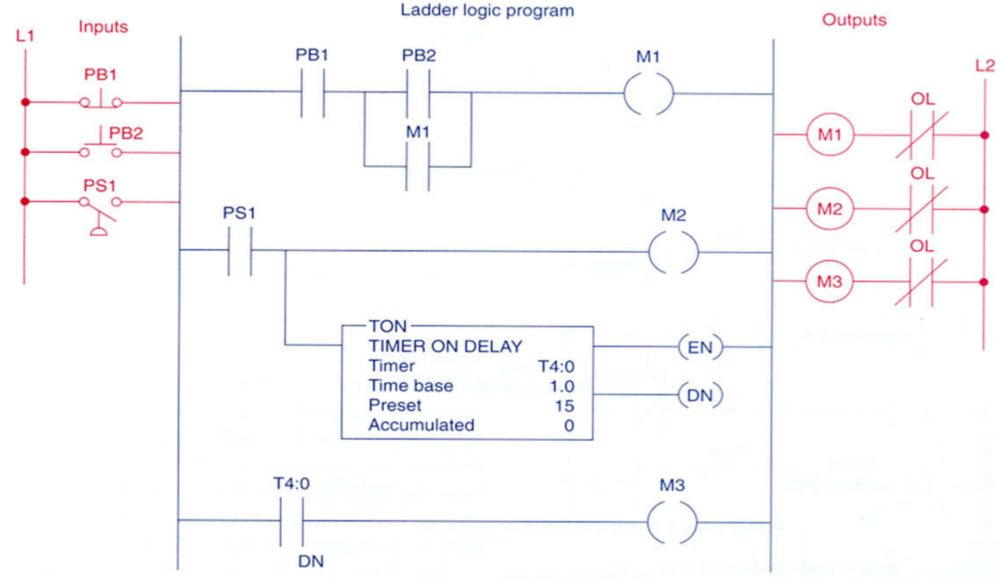
• If PB2 is activated, powers on the oil pumping motor.

• When the pressure augments, PS1 detects the increase and activates the main motor.

• 15 seconds later the main drive motor starts.



(a) Relay ladder schematic diagram



(b) Ladder logic

Fig. 7-15
Automatic sequential control system.

Ladder diagram

Example of *timer* programmed as *off-delay*

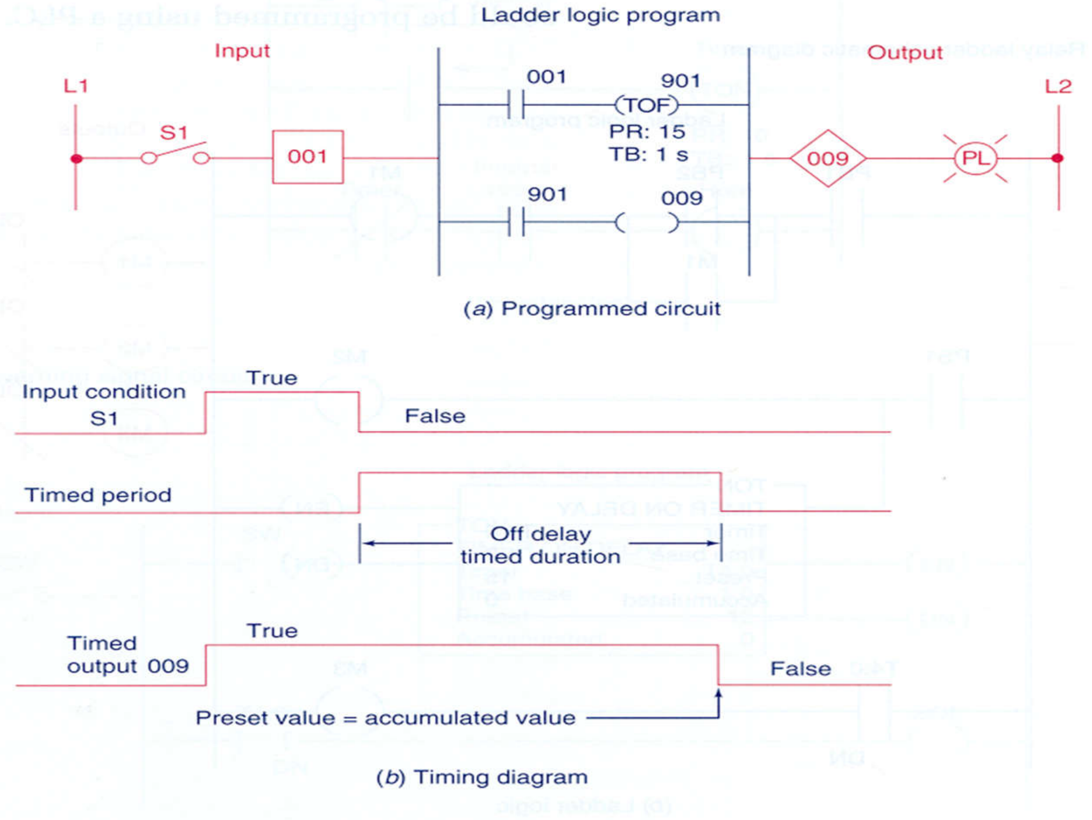


Fig. 7-16
Off-delay programmed timer.

Ladder diagram

Example of *timer* programmed as *off-delay*

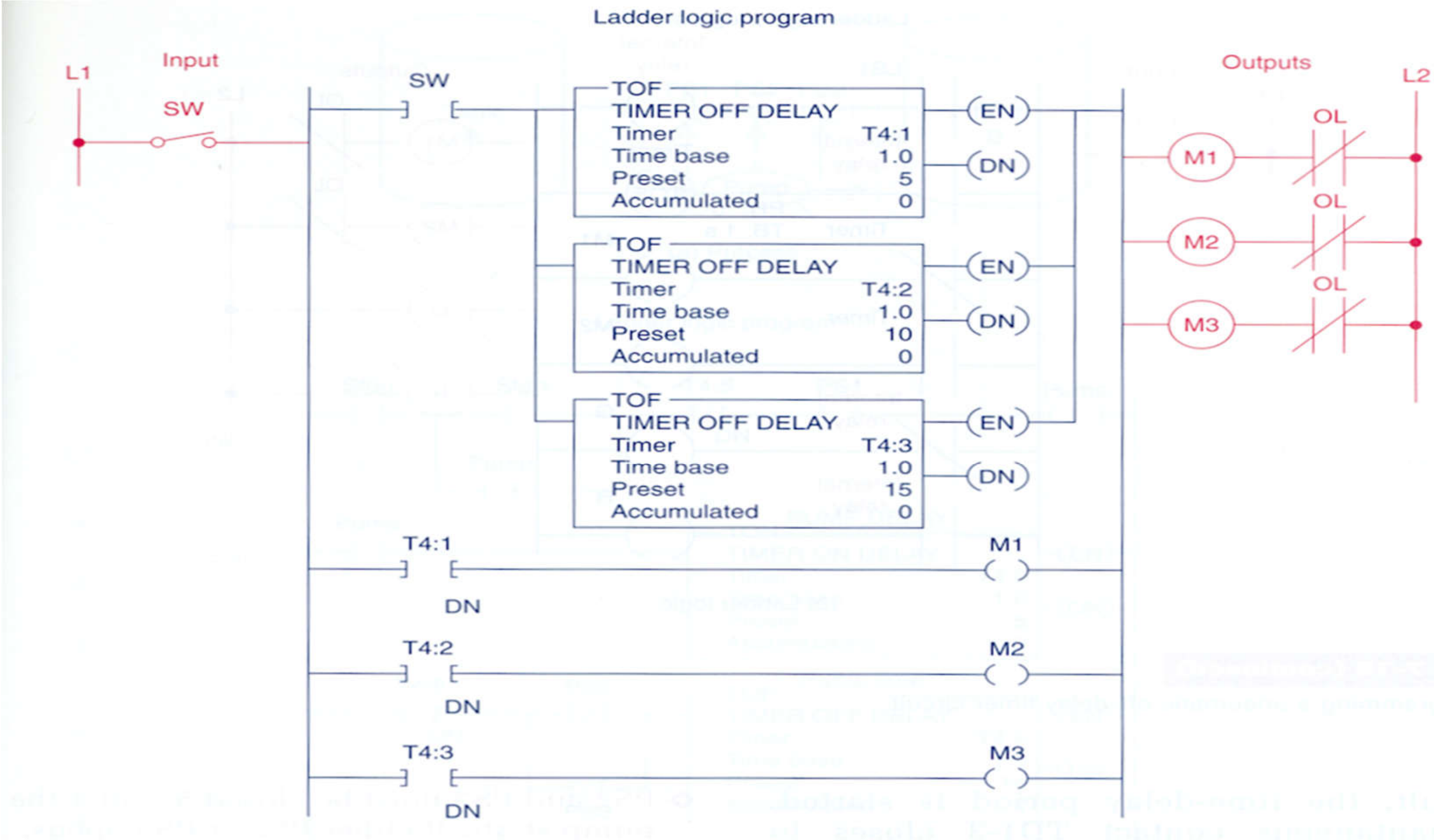
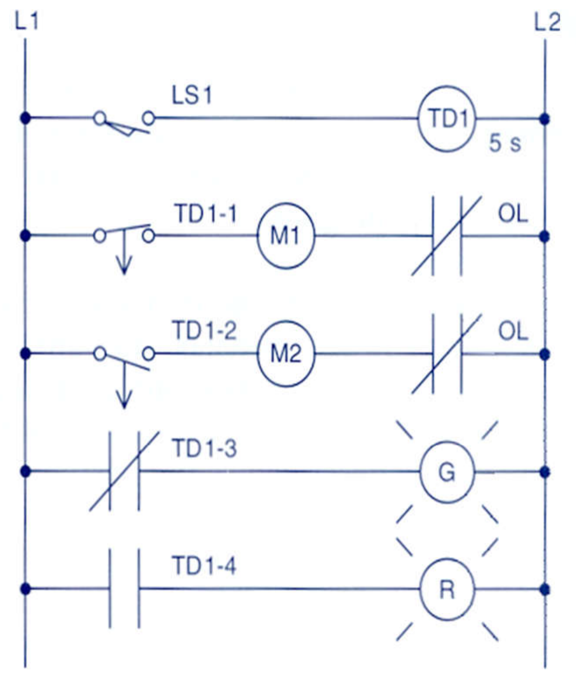


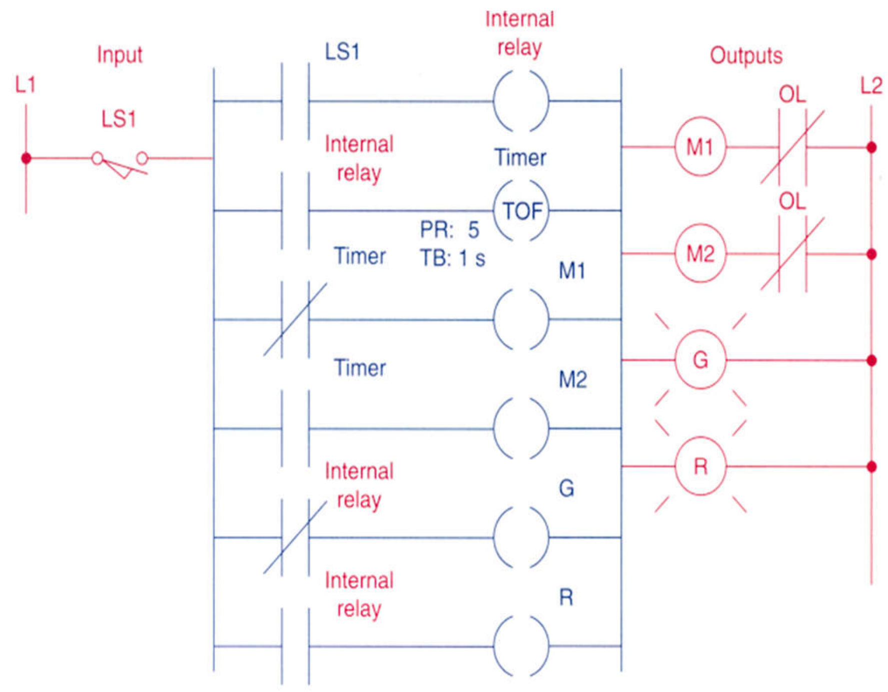
Fig. 7-17
Off-delay timer instructions programmed to switch motors off at 5-s intervals.

Ladder diagram

Example of *timer* programmed as *off-delay*



(*a*) Relay schematic diagram



(*b*) Ladder logic

Fig. 7-18
Programming a pneumatic off-delay timer circuit.

Fig. 7-18 (continued)
Programming a pneumatic off-delay timer circuit.

Ladder diagram

Example of *timers* programmed as *off-delay* and *on-delay*

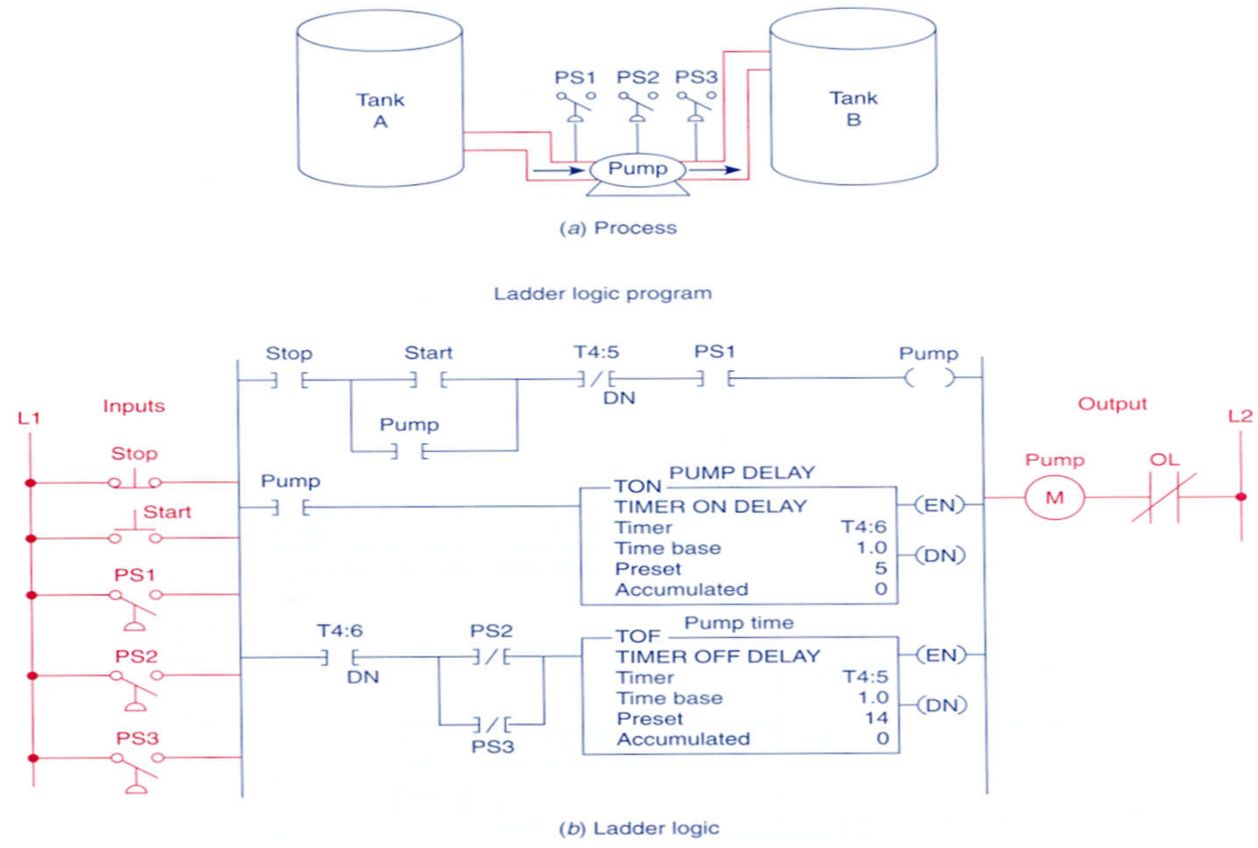
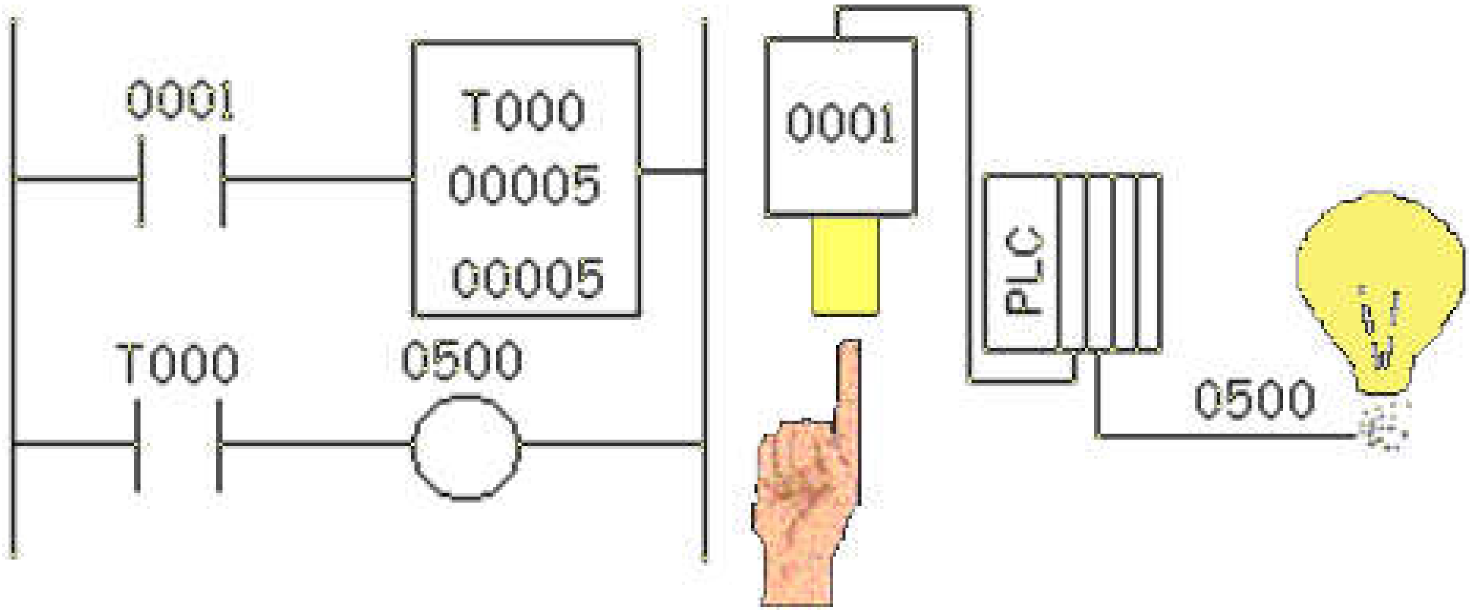


Fig. 7-19

Ladder diagram

Timers

Animated demonstration:



Ladder diagram

Retentive Timers

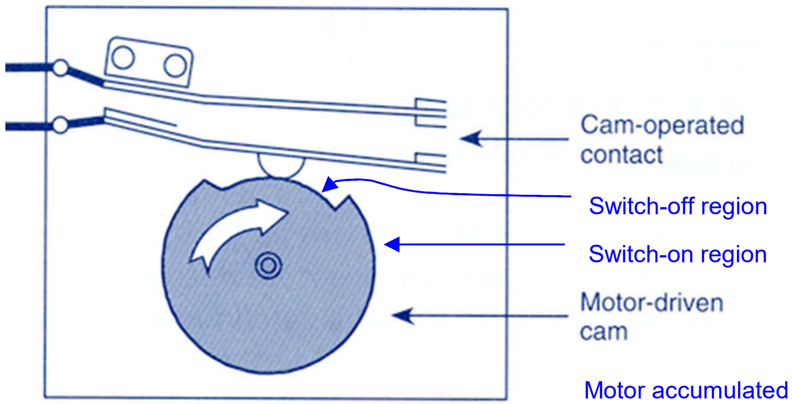
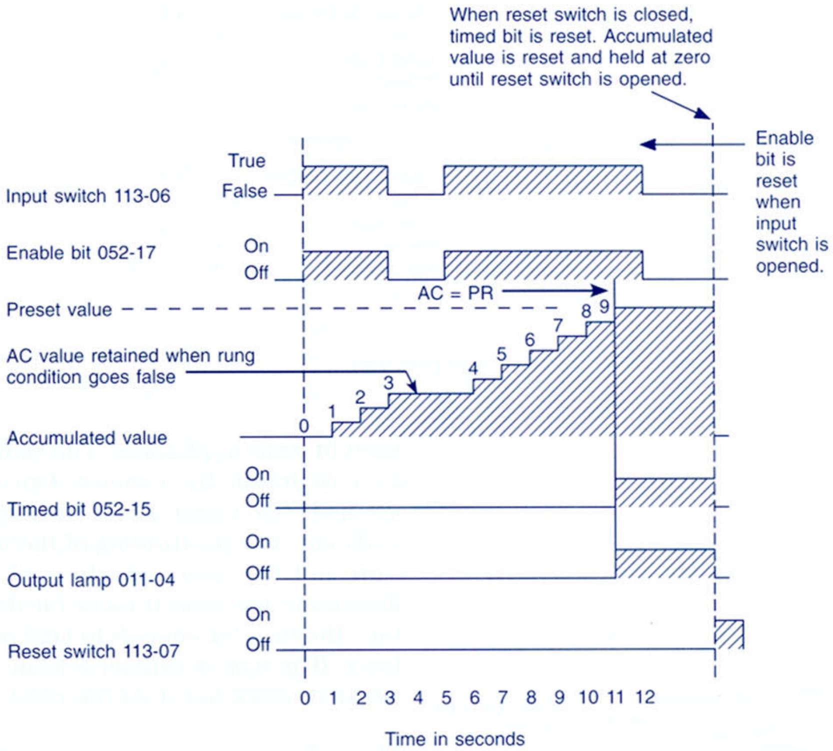
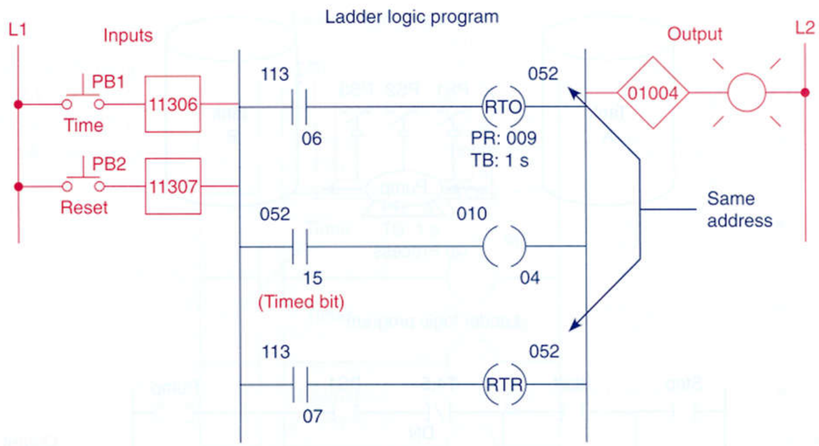


Fig. 7-20 Electromechanical retentive timer.



(*b*) Timing chart



(*a*) Programmed logic

Ladder diagram

Example of *retentive timers*

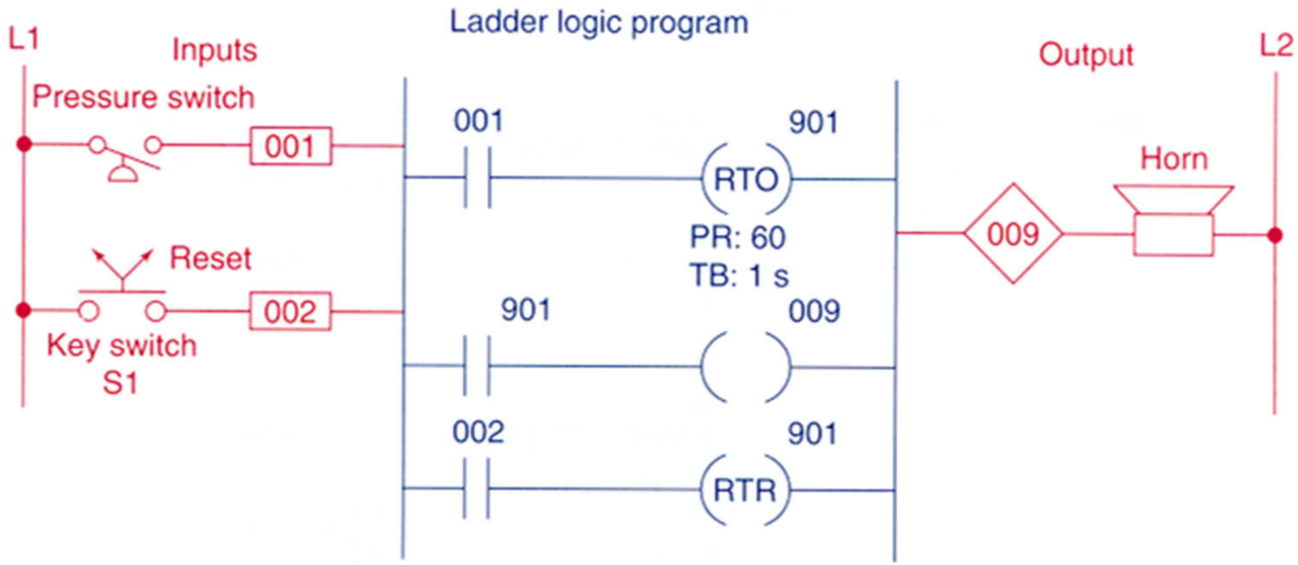


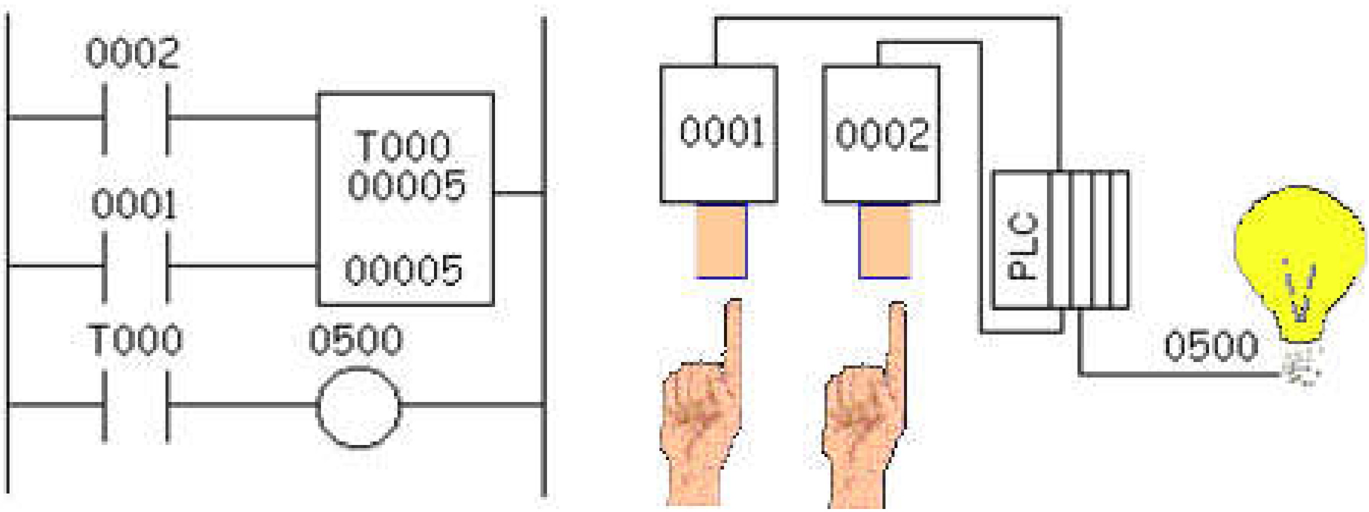
Fig. 7-22

Retentive on-delay alarm program.

Ladder diagrams *Retentive Timers*

Animated demonstration:

(search this function on Schneider PLCs or discuss implementation)



T000 = retentive timer
0002 = push button (counted while ON)
0001 = reset push button
0500 = lamp output

Ladder diagram

Example:

• SW ON to start operation

• Before motor starts, lubrificate 10 s with oil.

• SW OFF to stop. (lubrificate 15 s more).

• After 3 hours of pump operation, stop motor and signal with pilot light.

• Reset available after servicing.

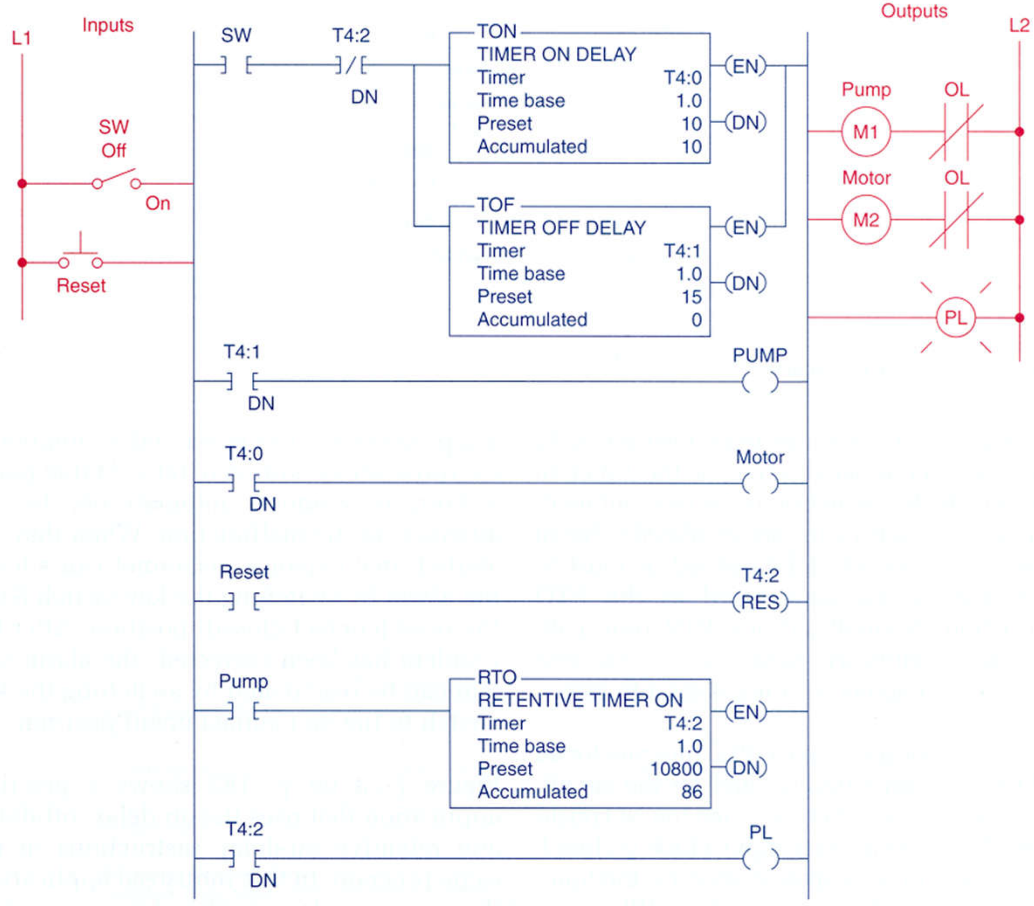
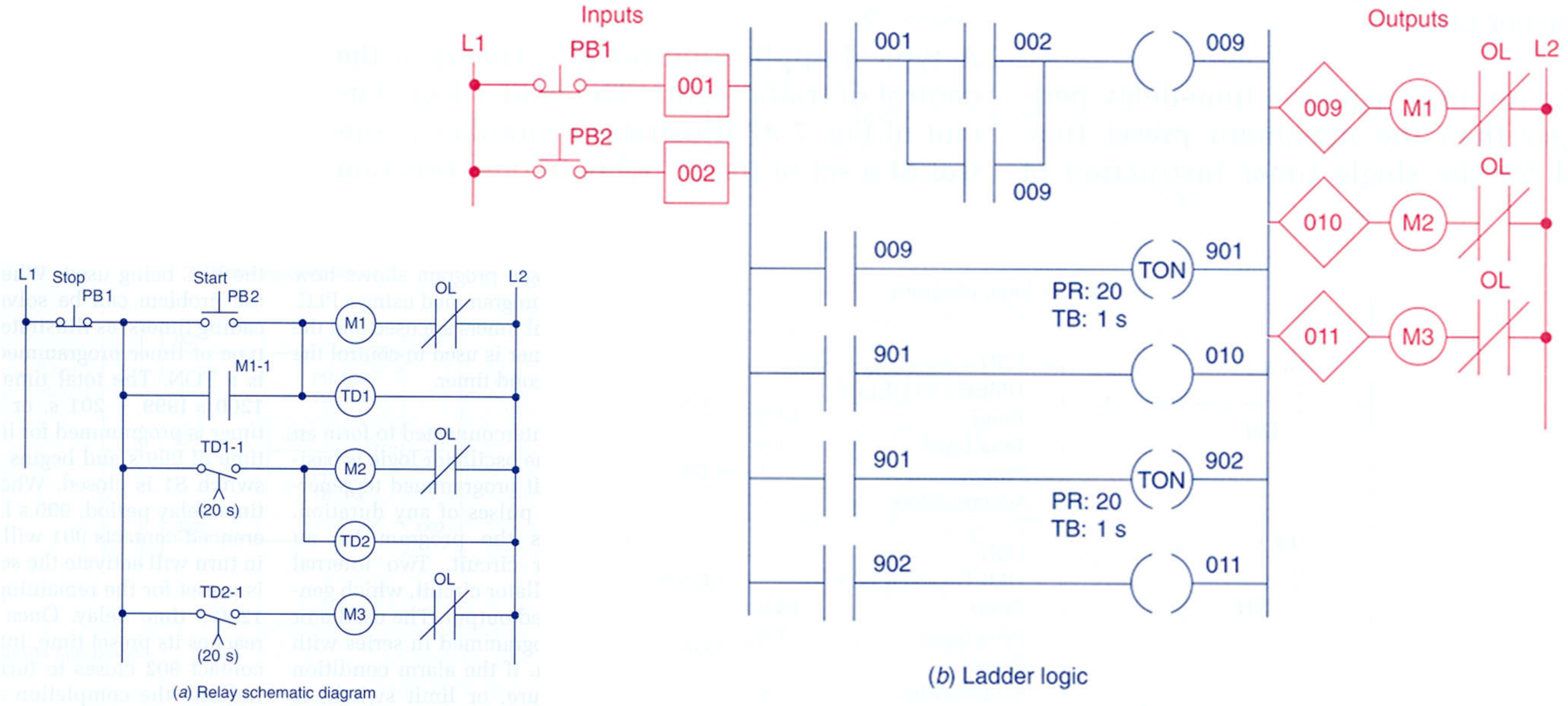


Fig. 7-23
Bearing lubrication program.

Ladder diagram

Cascaded Timers



(a) Relay schematic diagram

(b) Ladder logic

Fig. 7-24

Sequential time-delayed motor-starting circuit.

Start 3 motors
T=0, t=20, t=40sec

Ladder diagram

Cascaded Timers (bistable system)

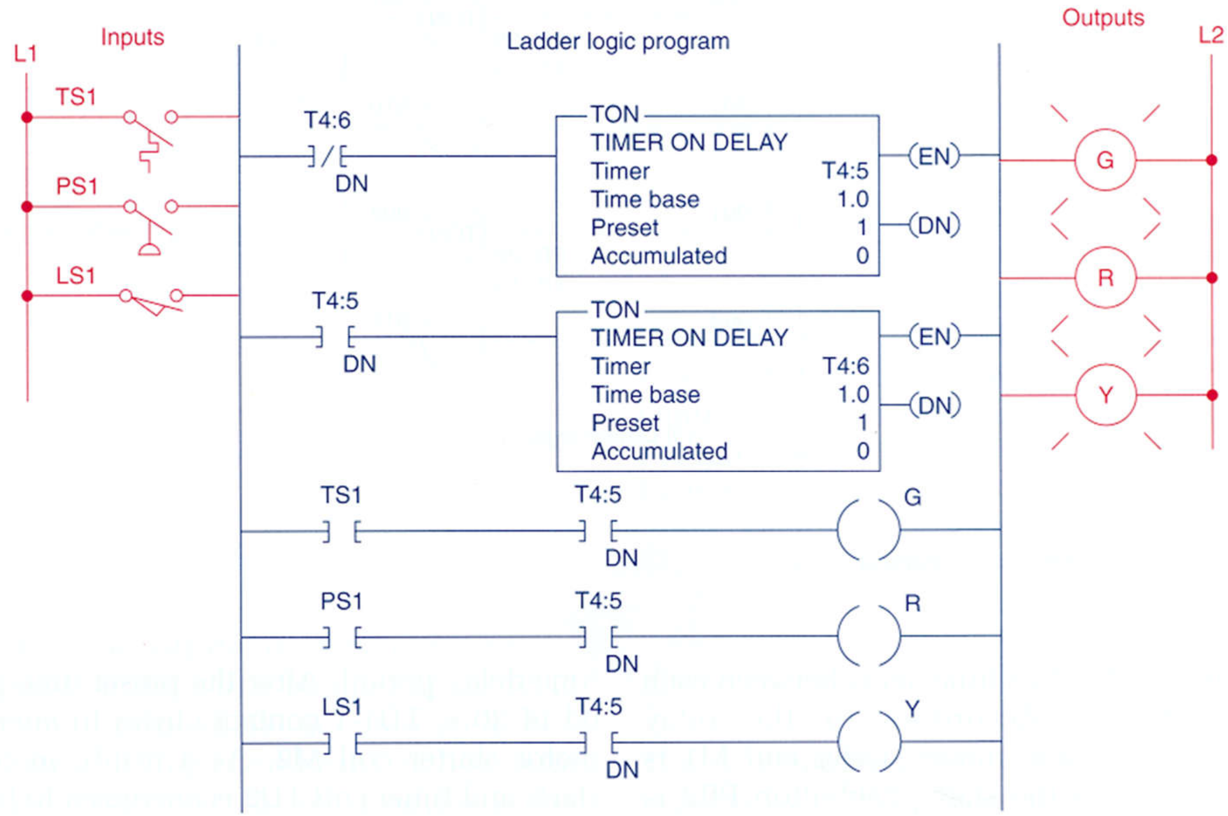


Fig. 7-25
Annunciator flasher program.

Ladder diagram

Timers for very long time intervals

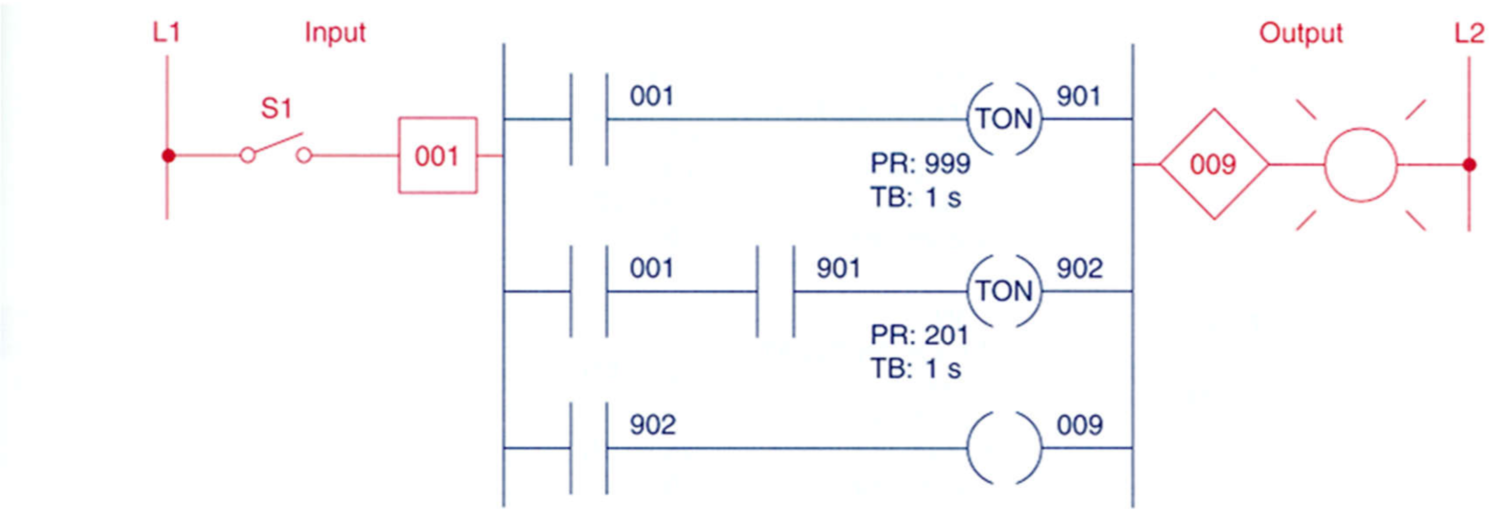
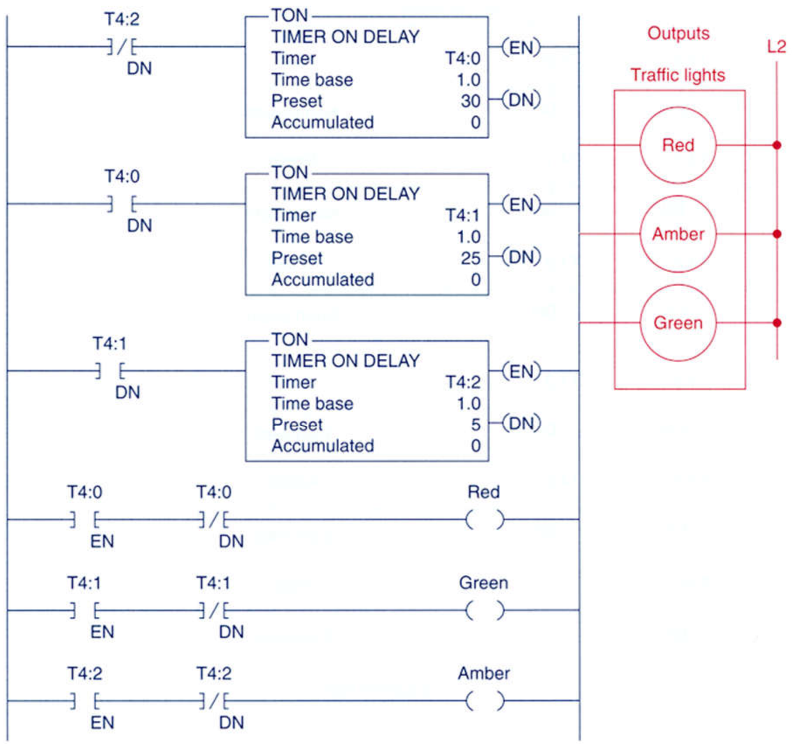
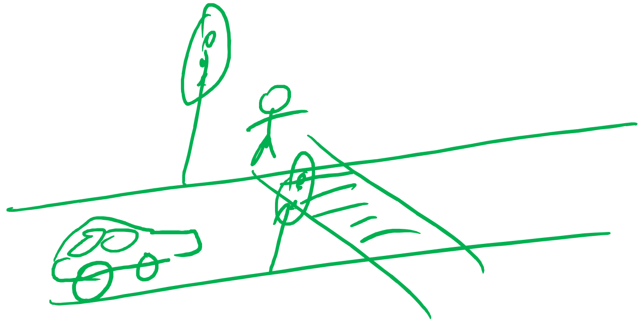


Fig. 7-26
Cascading of timers for longer time delays.

Ladder diagram

Example of a semaphore

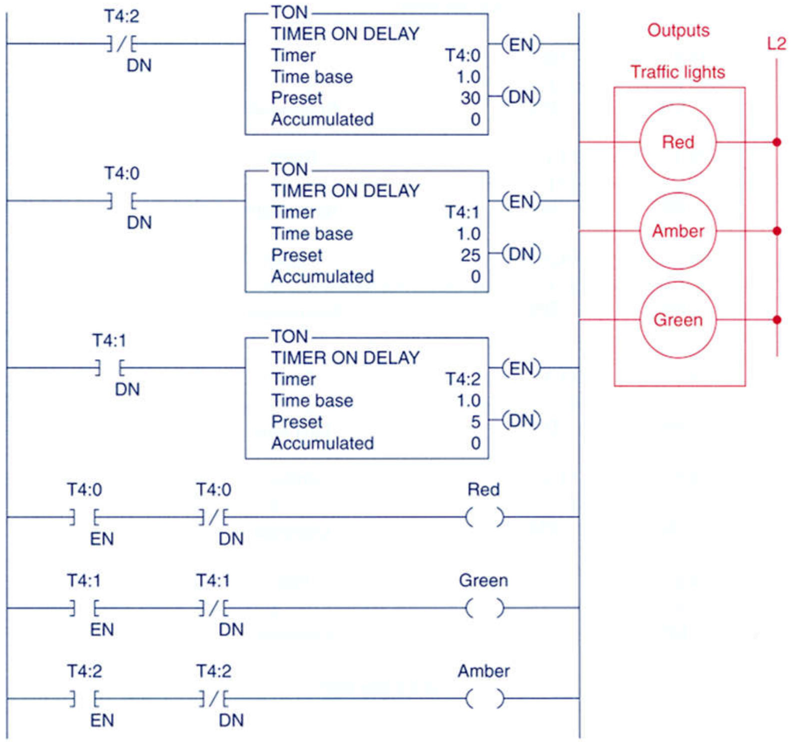


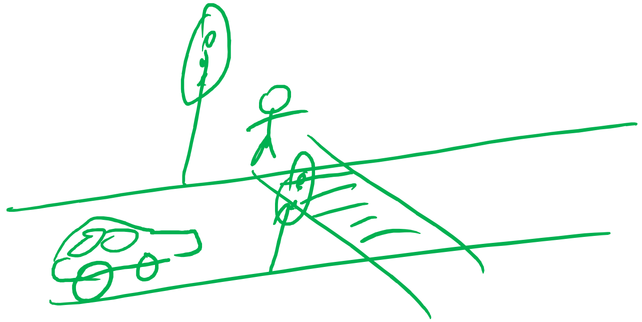


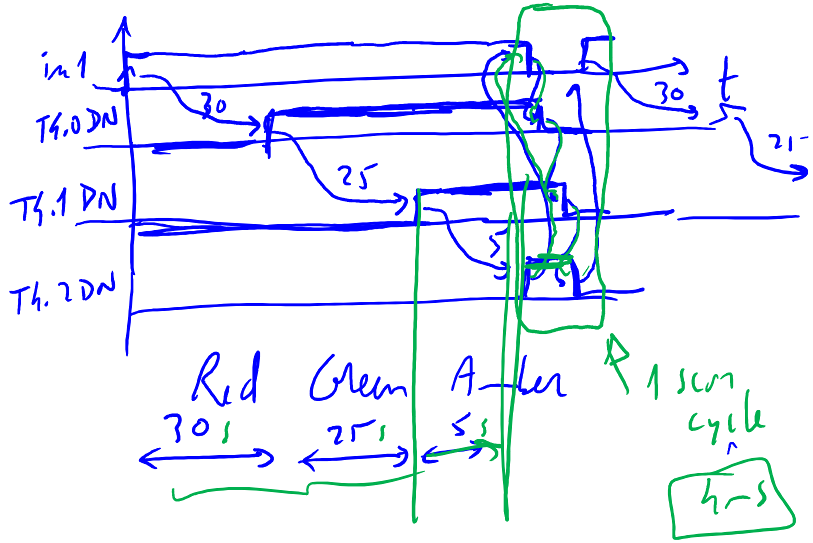
Red	30 s on
Green	25 s on
Amber	5 s on

Fig. 7-27
Control of traffic lights in one direction.

Ladder diagram Example of a semaphore



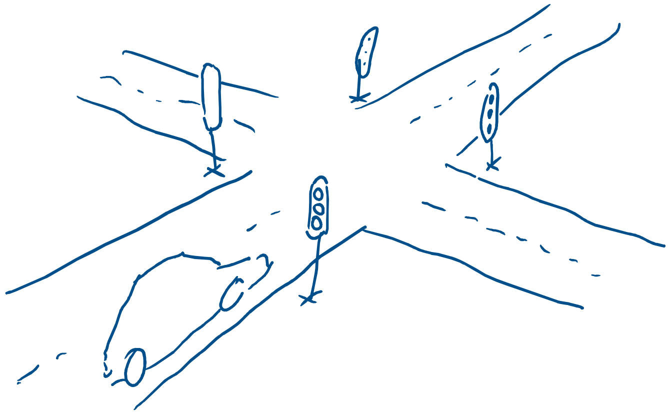




Red	30 s on
Green	25 s on
Amber	5 s on

Example of a semaphore in both directions

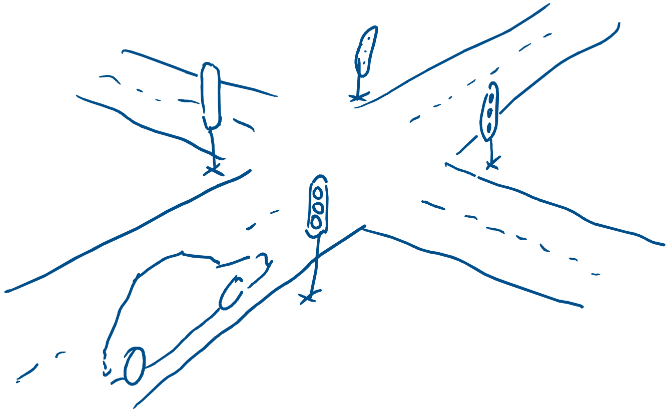
Red	30 s on
Green	25 s on
Amber	5 s on

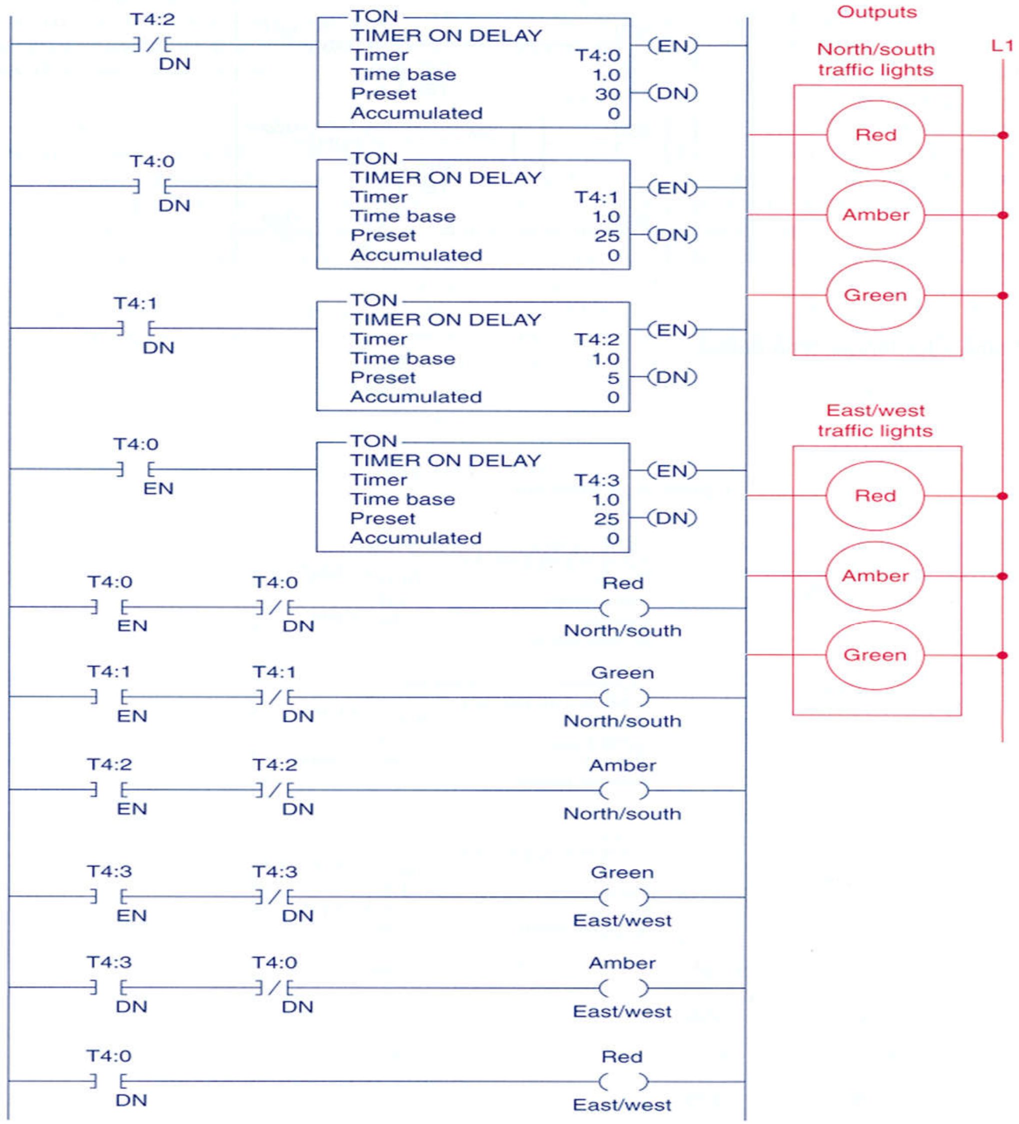


(b) Timing chart

Fig. 7-28 (continued)
Control of traffic lights in two directions.

Example of a semaphore in both directions

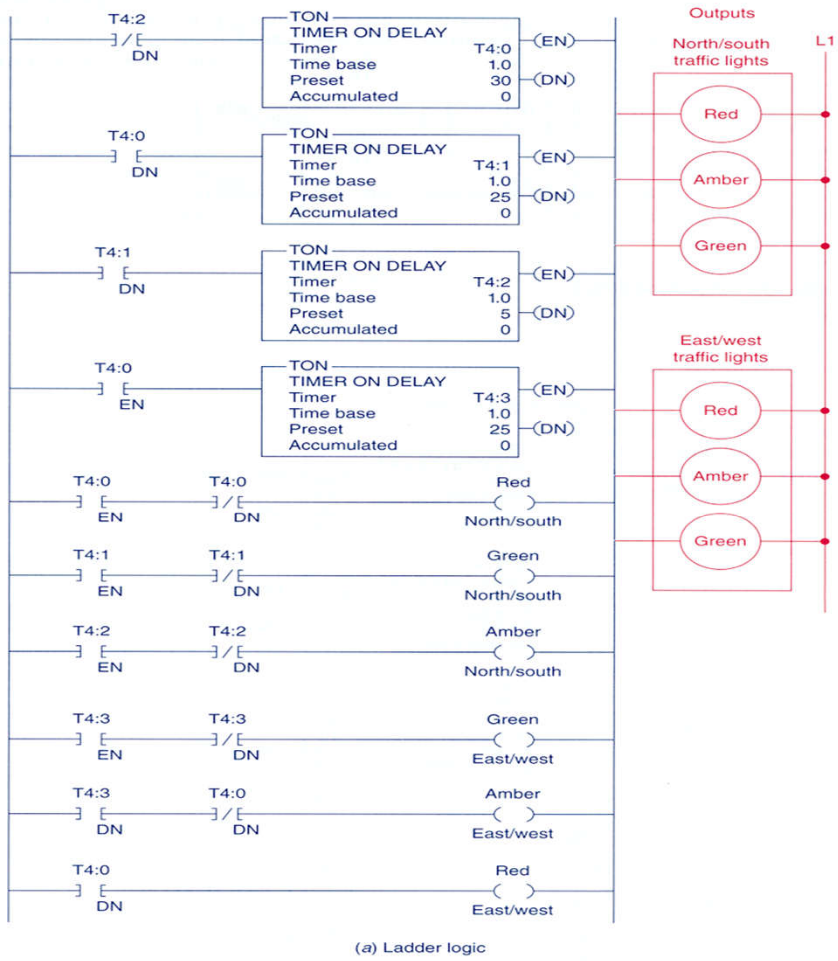




(a) Ladder logic

Fig. 7-28
Control of traffic lights in two directions.

Example of a semaphore in both directions



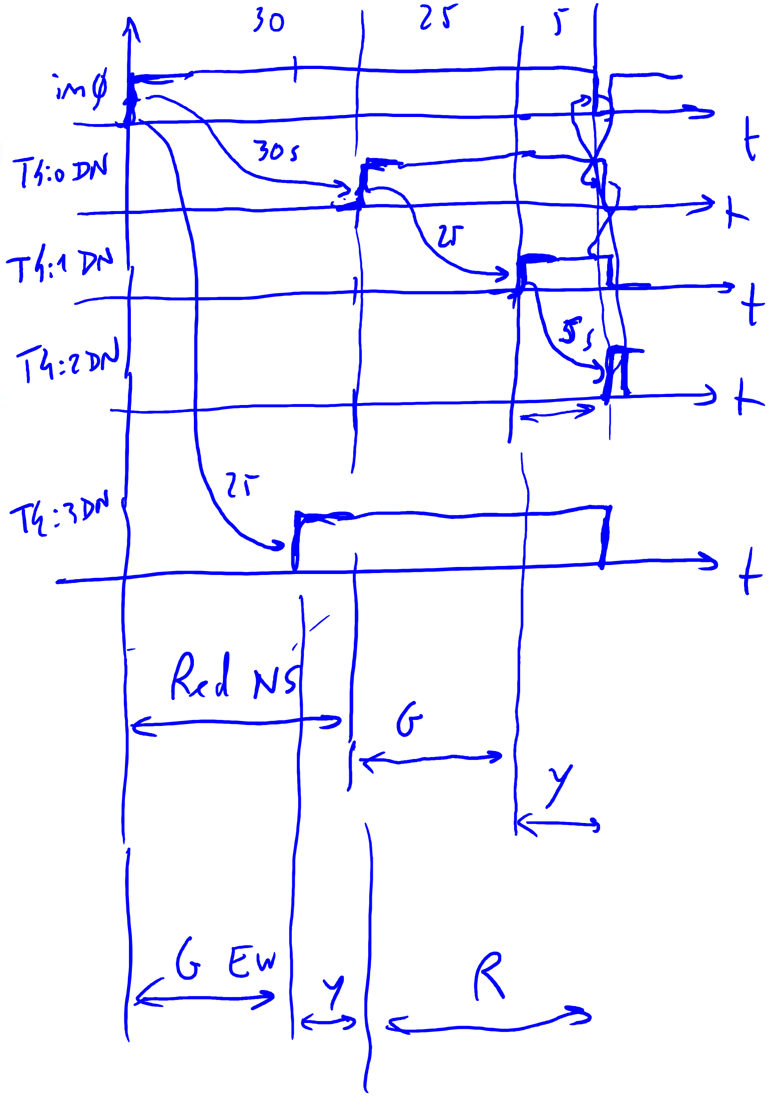


Fig. 7-28
Control of traffic lights in two directions.

Ladder diagram

Counters

Some applications...

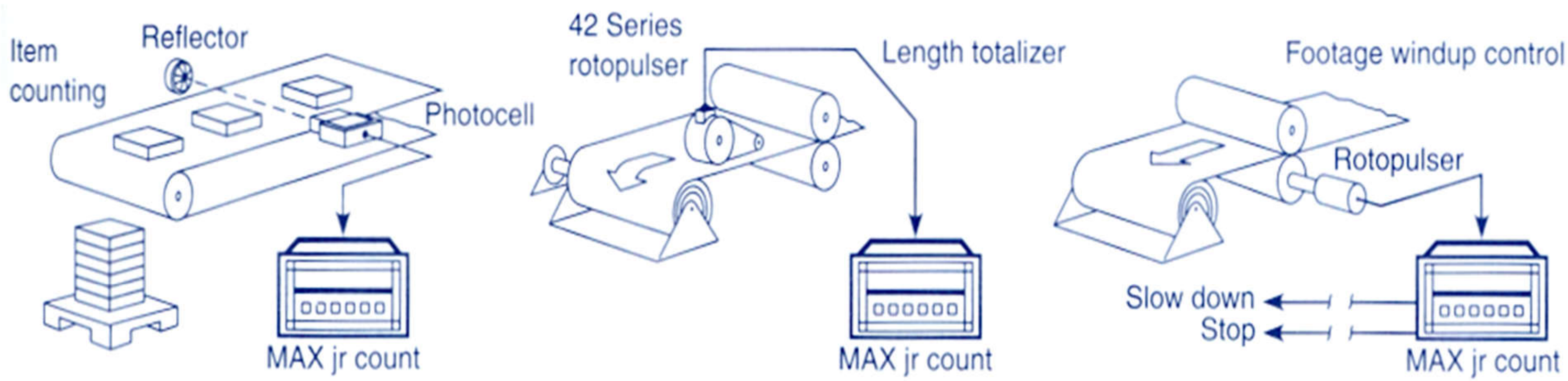
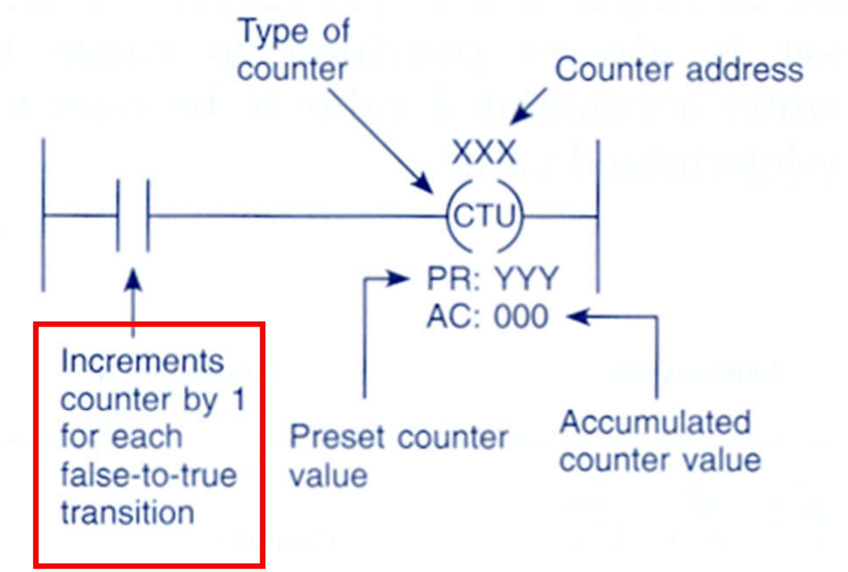


Fig. 8-3

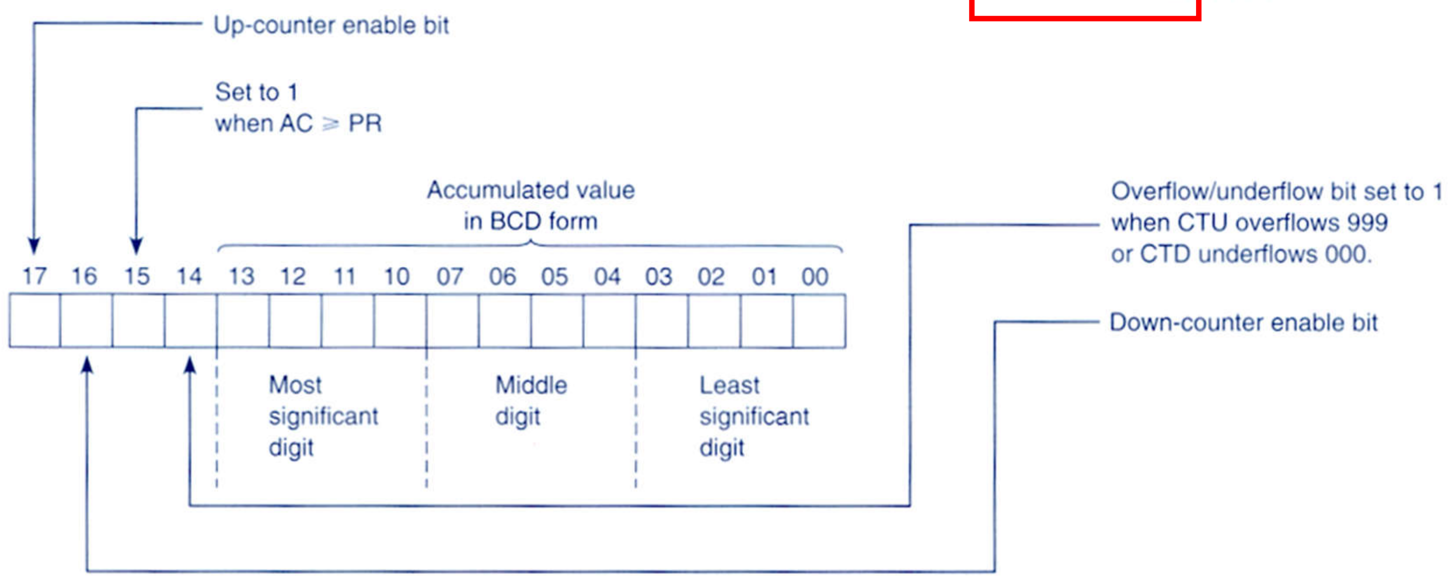
Counter applications. *(Courtesy of Dynapar Corporation, Gurnee, Illinois.)*

Ladder diagram

Implementation of Counters in the PLC-5 of *Allen-Bradley*:



Internal structure representation

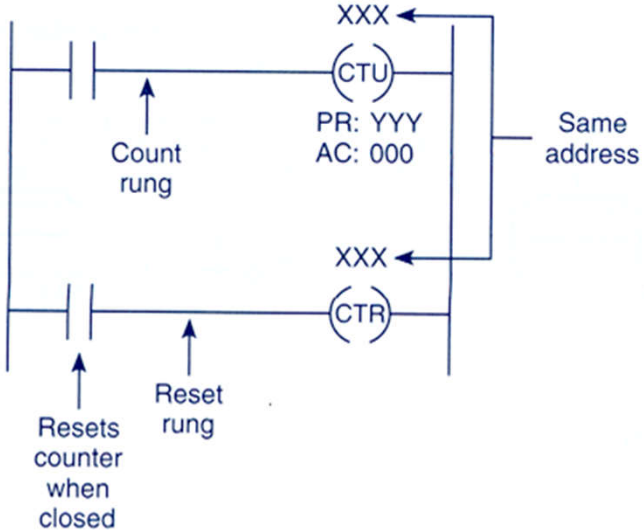


(*b*) Allen-Bradley PLC-2 timer accumulated value word
(bit addressing is in octal)

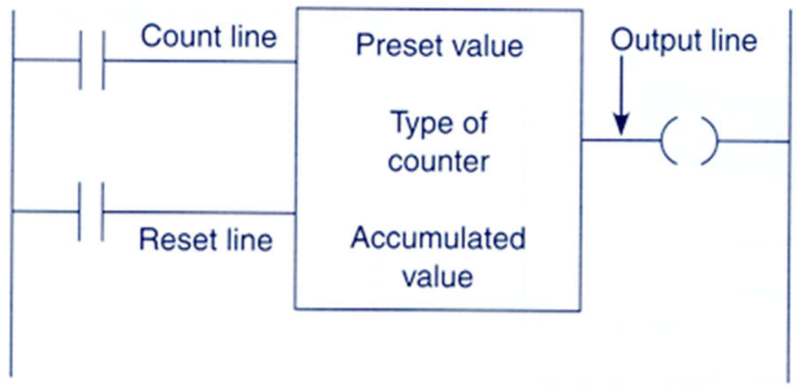
Ladder diagram

Implementation of Counters in the PLC-5 of *Allen-Bradley*:

Two alternative representations:



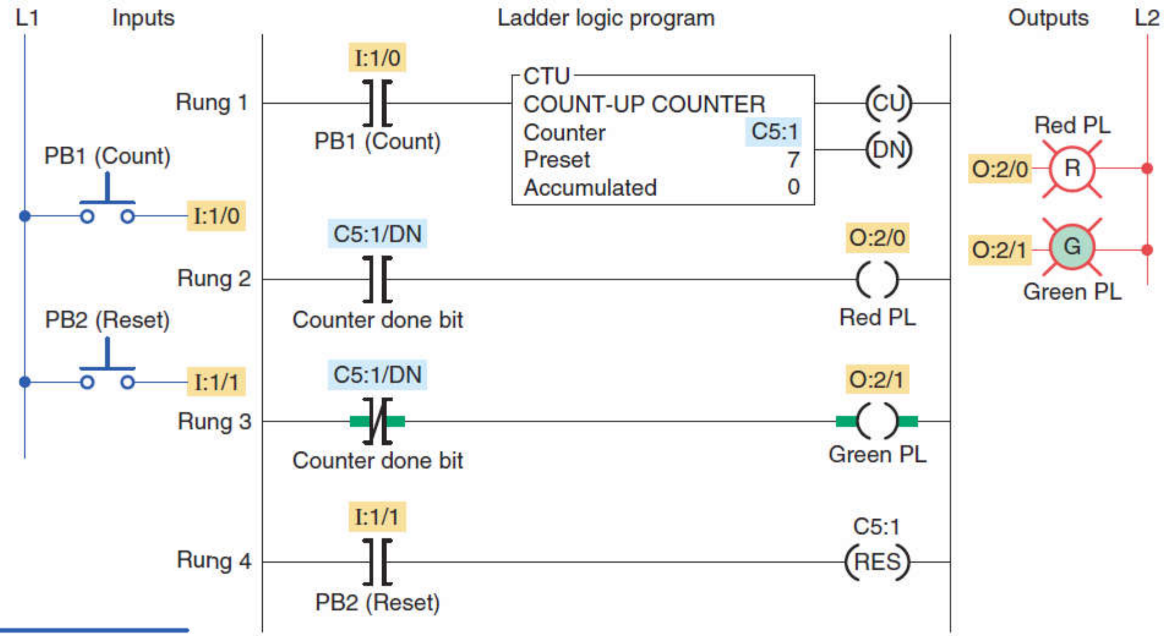
Coil-formatted counter and reset instructions

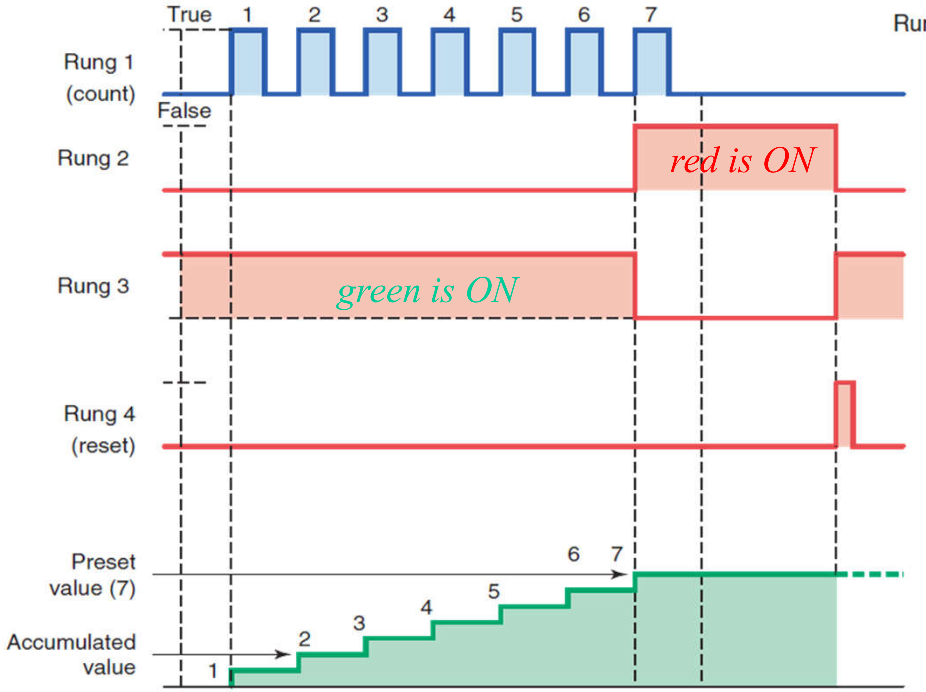


Block-formatted counter instruction

Ladder diagram

Up-counters

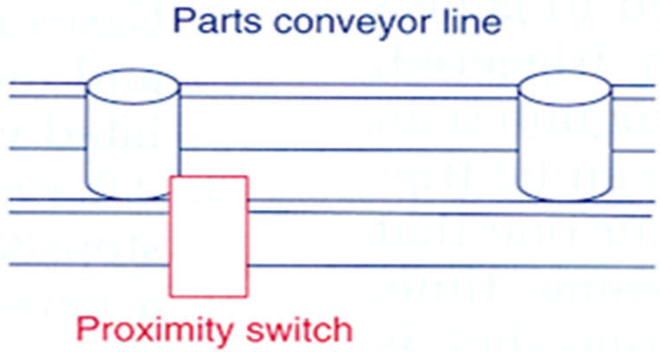




Usage of an **incremental up-counter** and the corresponding **temporal diagram:**

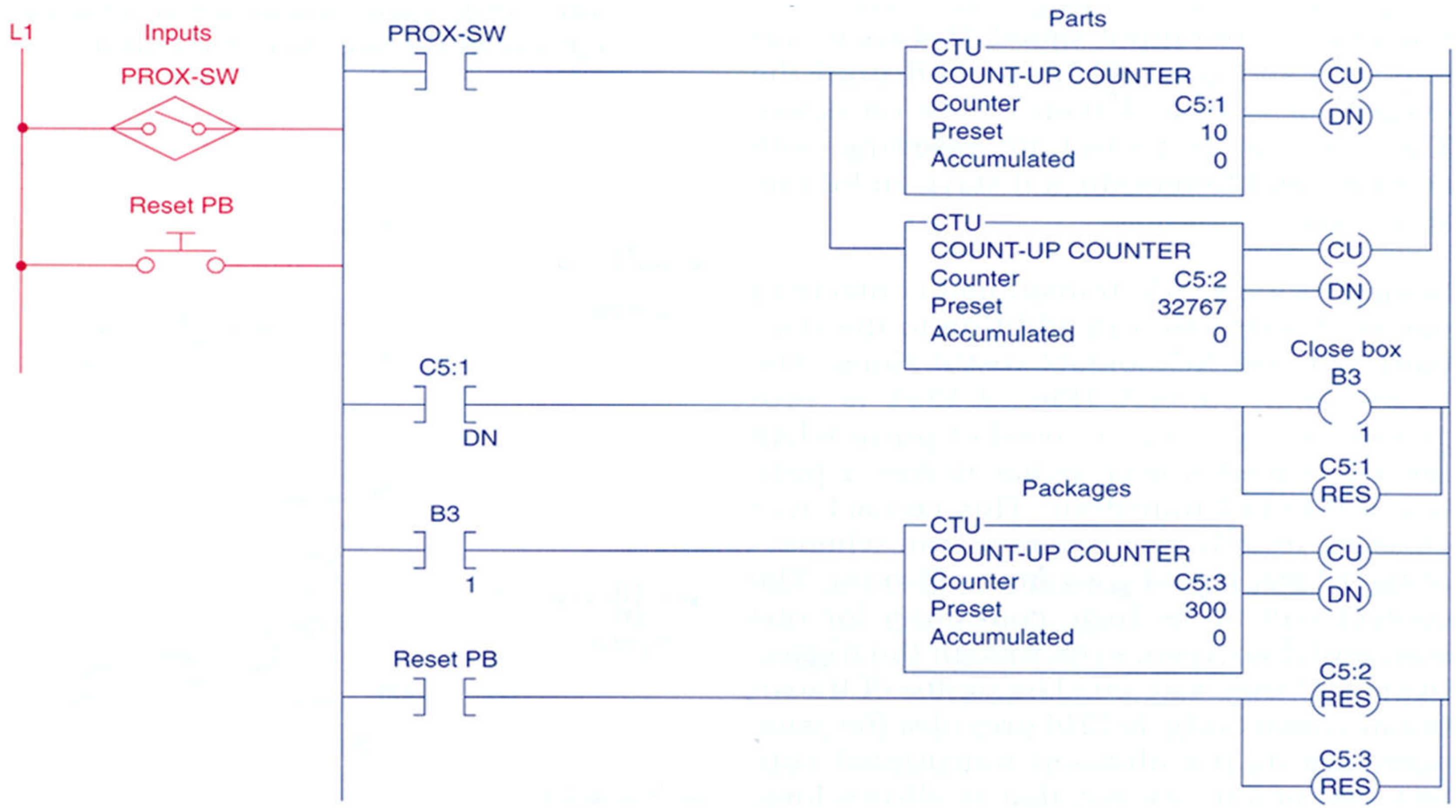
PB1 increments counting
PB2 resets the counting

Ladder diagram



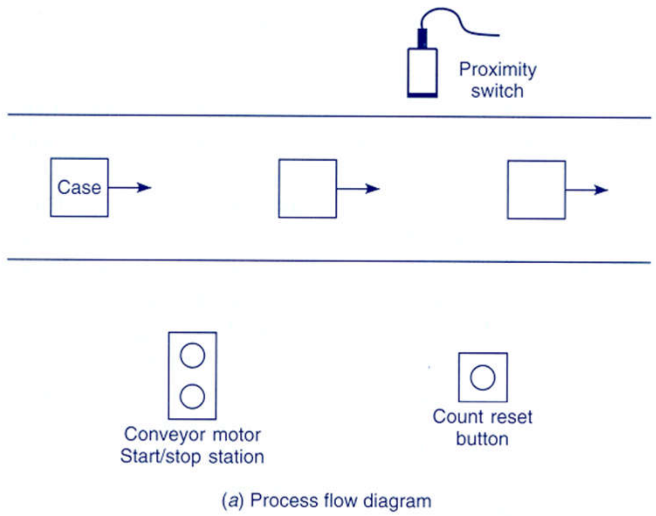
Example:

Counting parts



Ladder diagram

Example



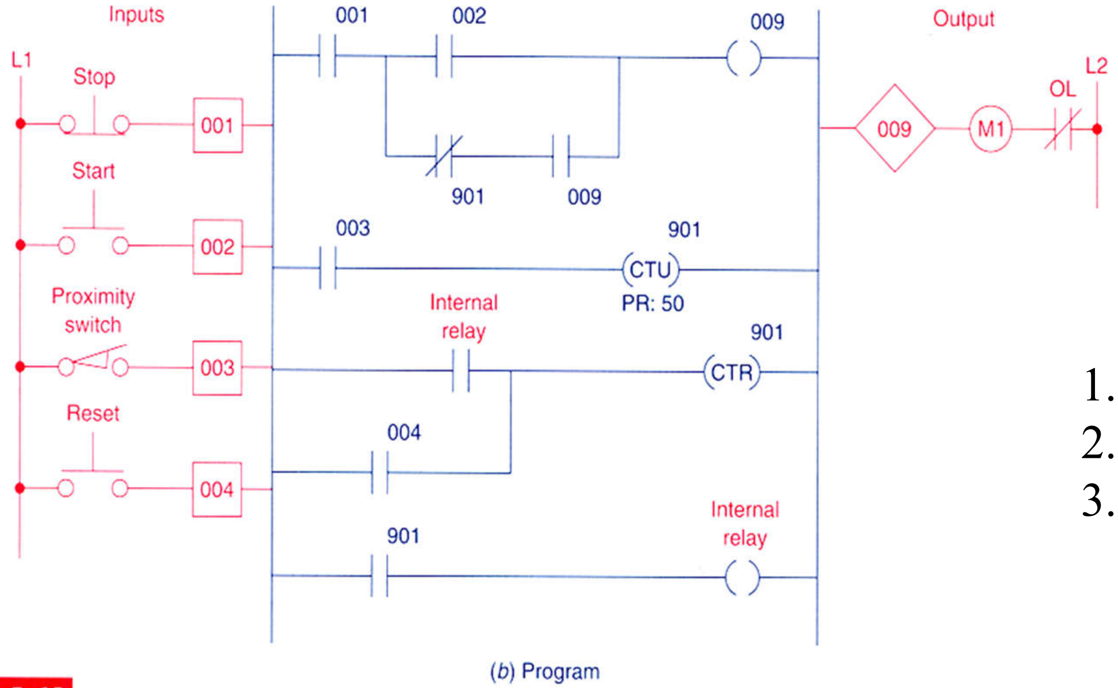
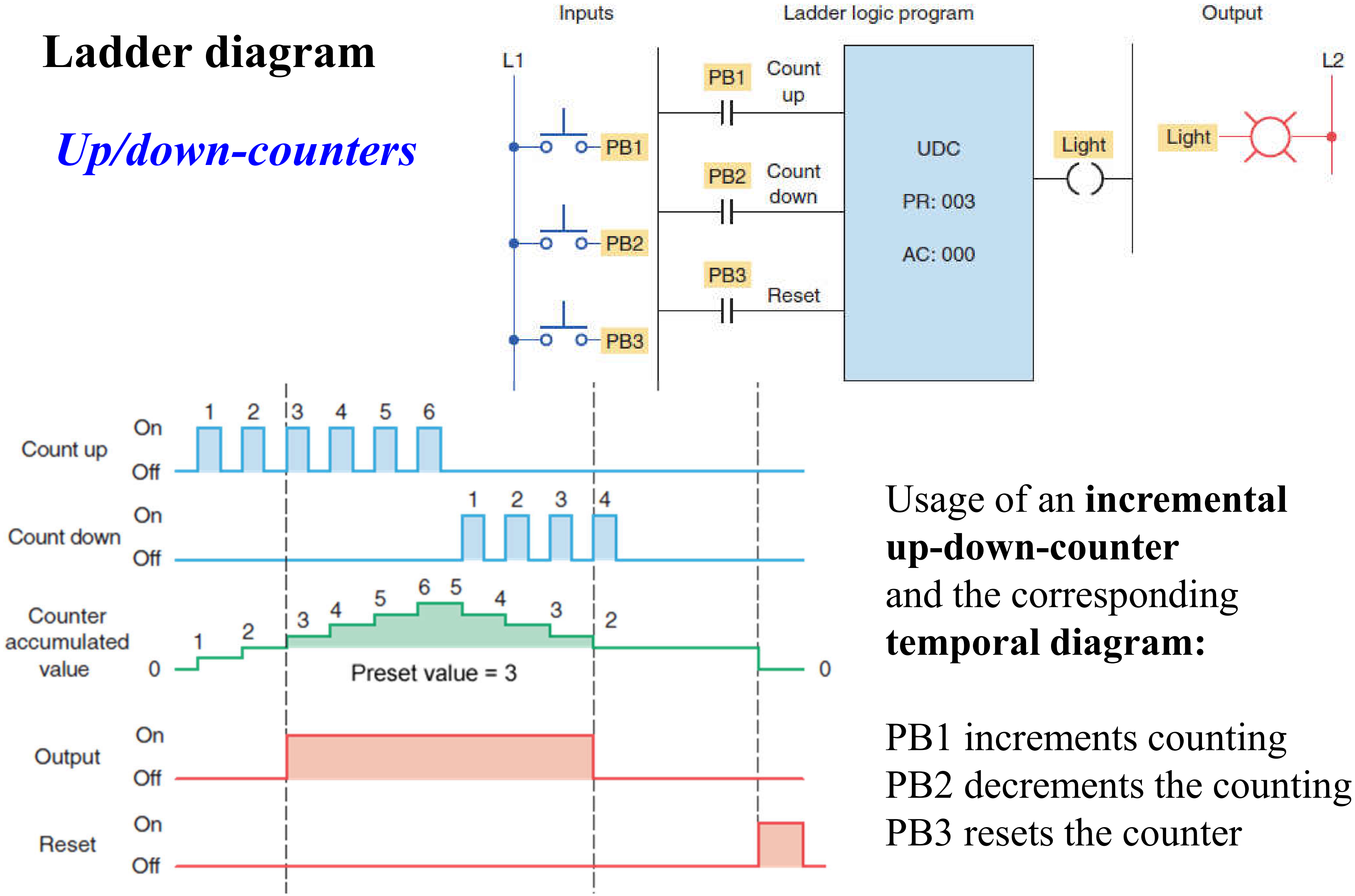


Fig. 8-13
Conveyor motor program.

1. Start conveyor motor
2. Passing cases increment counter
3. After 50 cases, stop motor

Ladder diagram

Up/down-counters



Usage of an **incremental up-down-counter** and the corresponding **temporal diagram:**

PB1 increments counting
PB2 decrements the counting
PB3 resets the counter

Ladder diagram

Up/down-counters

Example:

Finite parking garage

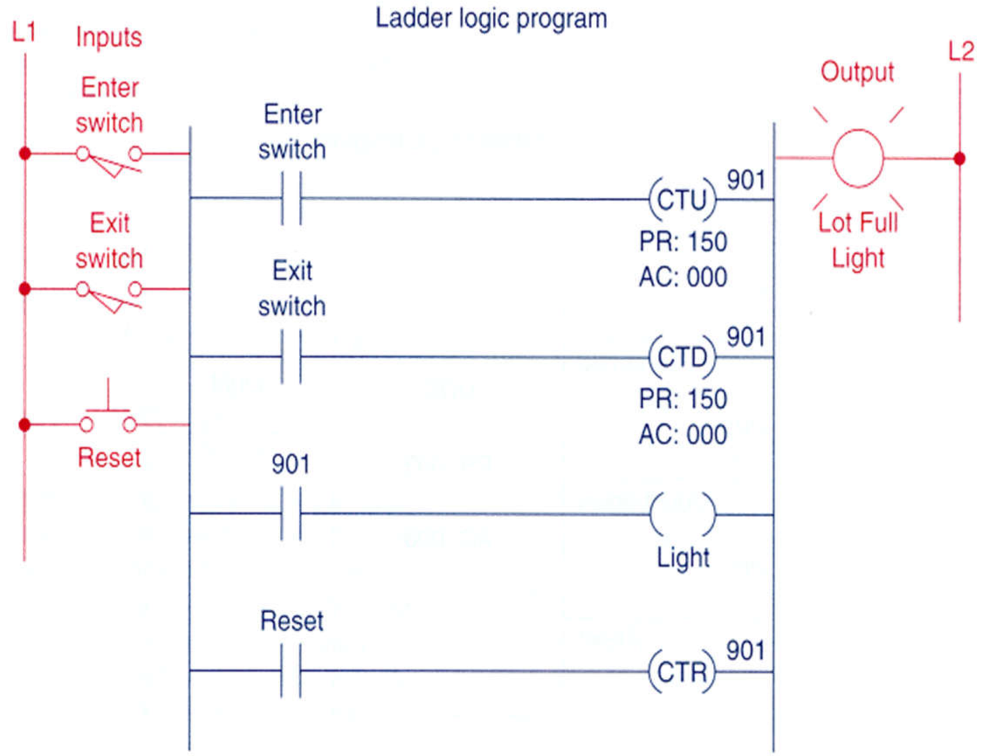


Fig. 8-17
Parking garage counter.

Ladder diagram

Cascaded Counters

Example:

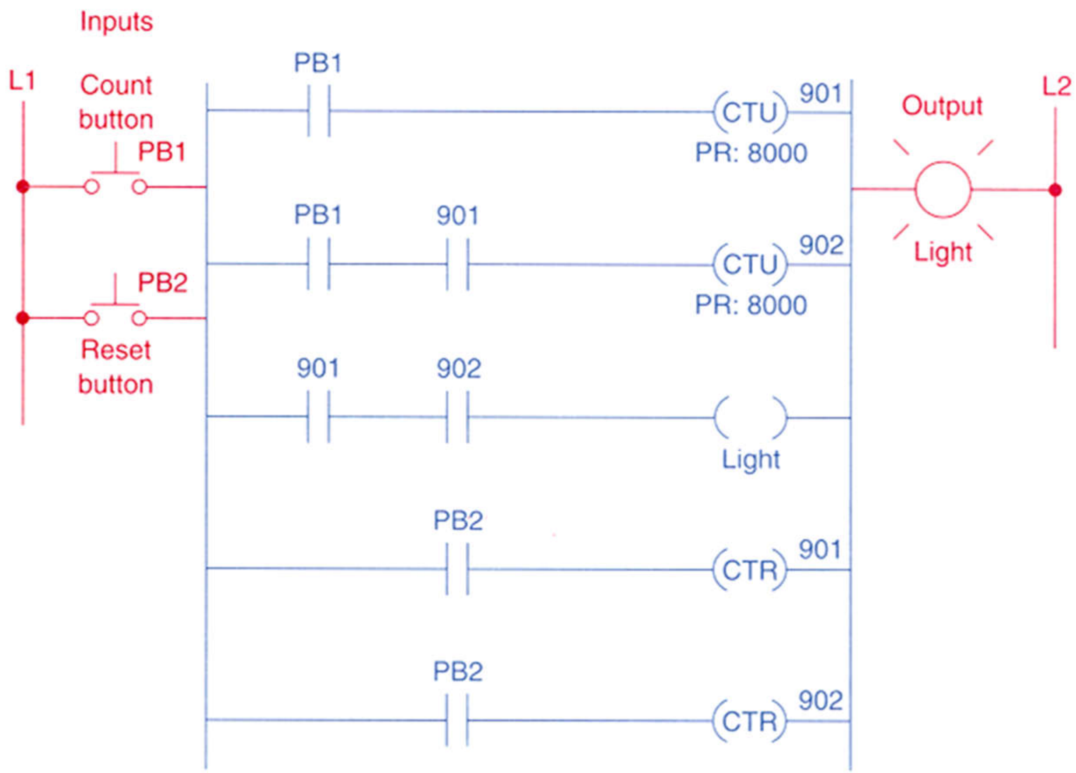


Fig. 8-21
Counting beyond the maximum count.

Ladder diagram

Cascaded Counters

Example:

24 hours clock

Note "auto-reset" of counters after "count-done".

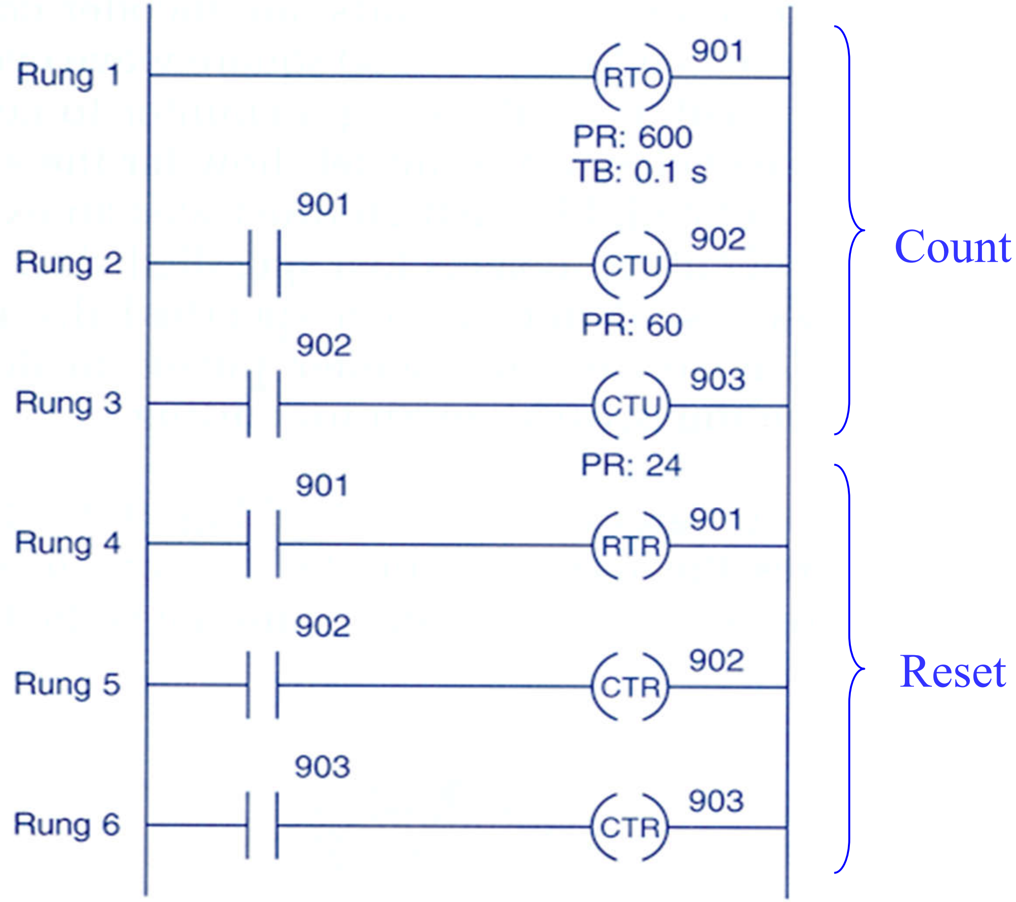


Fig. 8-23
A 24-h clock program.

Ladder diagram

Cascaded Counters

Example:

Memory time of event
Internal relay OFF stops clock

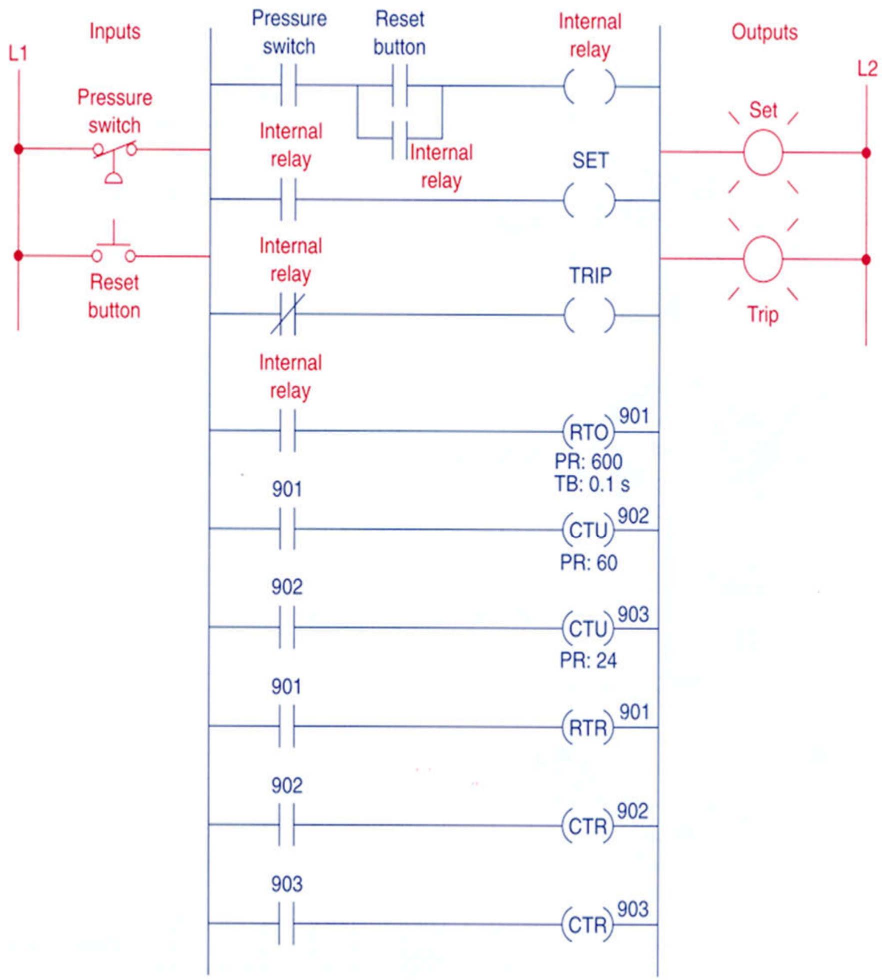


Fig. 8-24
Program for monitoring the time of an event.

Ladder diagram

Incremental *Encoder*

counter measures **rotation angle** or **rotation speed** (if divided by time)

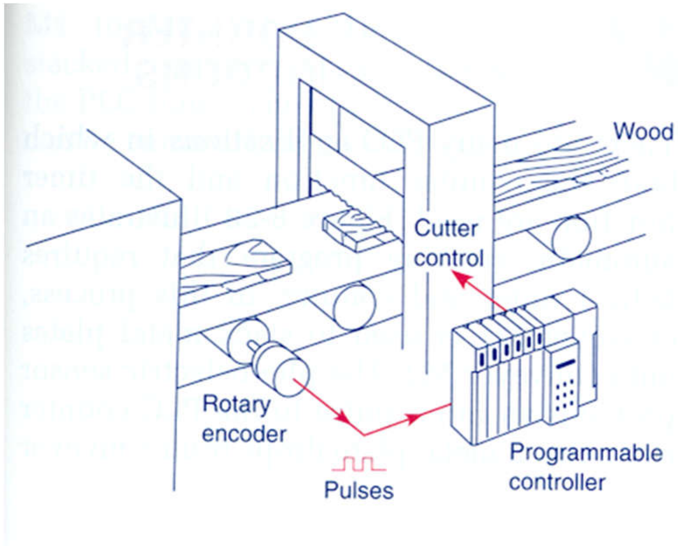


Fig. 8-26
Cutting objects to a specified size.

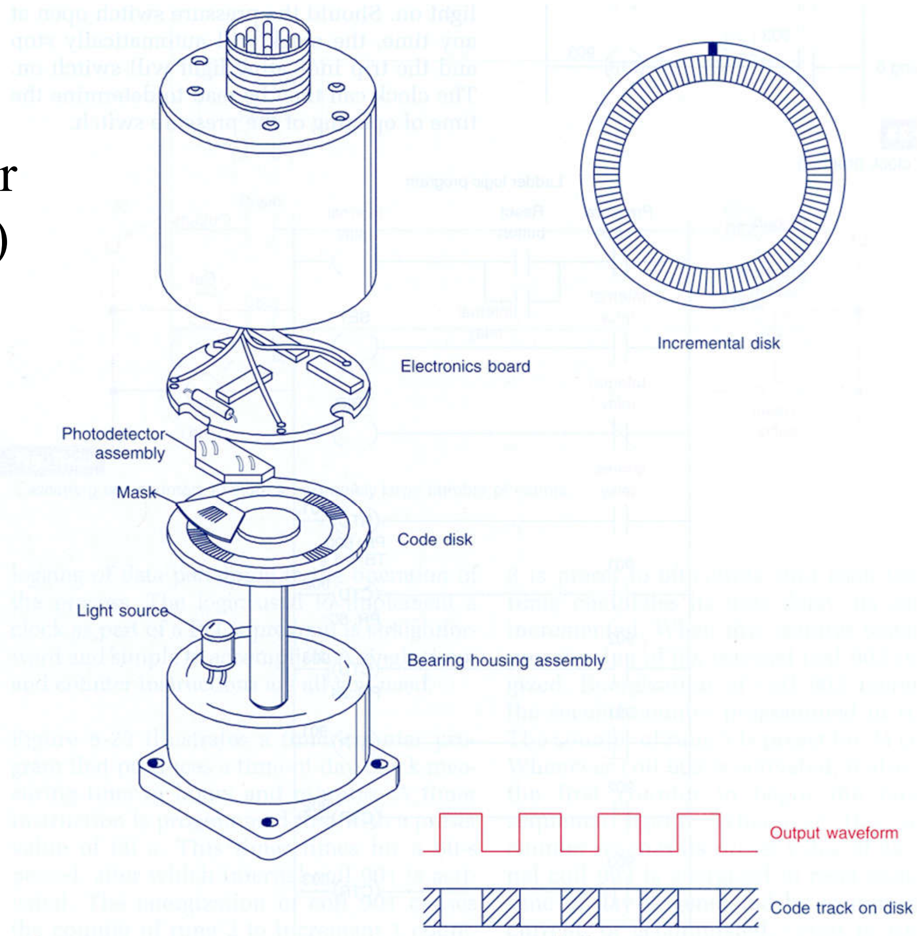


Fig. 8-25
Incremental encoder. *(Courtesy of BEI Motion Systems Company.)*

Ladder diagram

Incremental *Encoder*

Example:
counter as a ”length sensor”

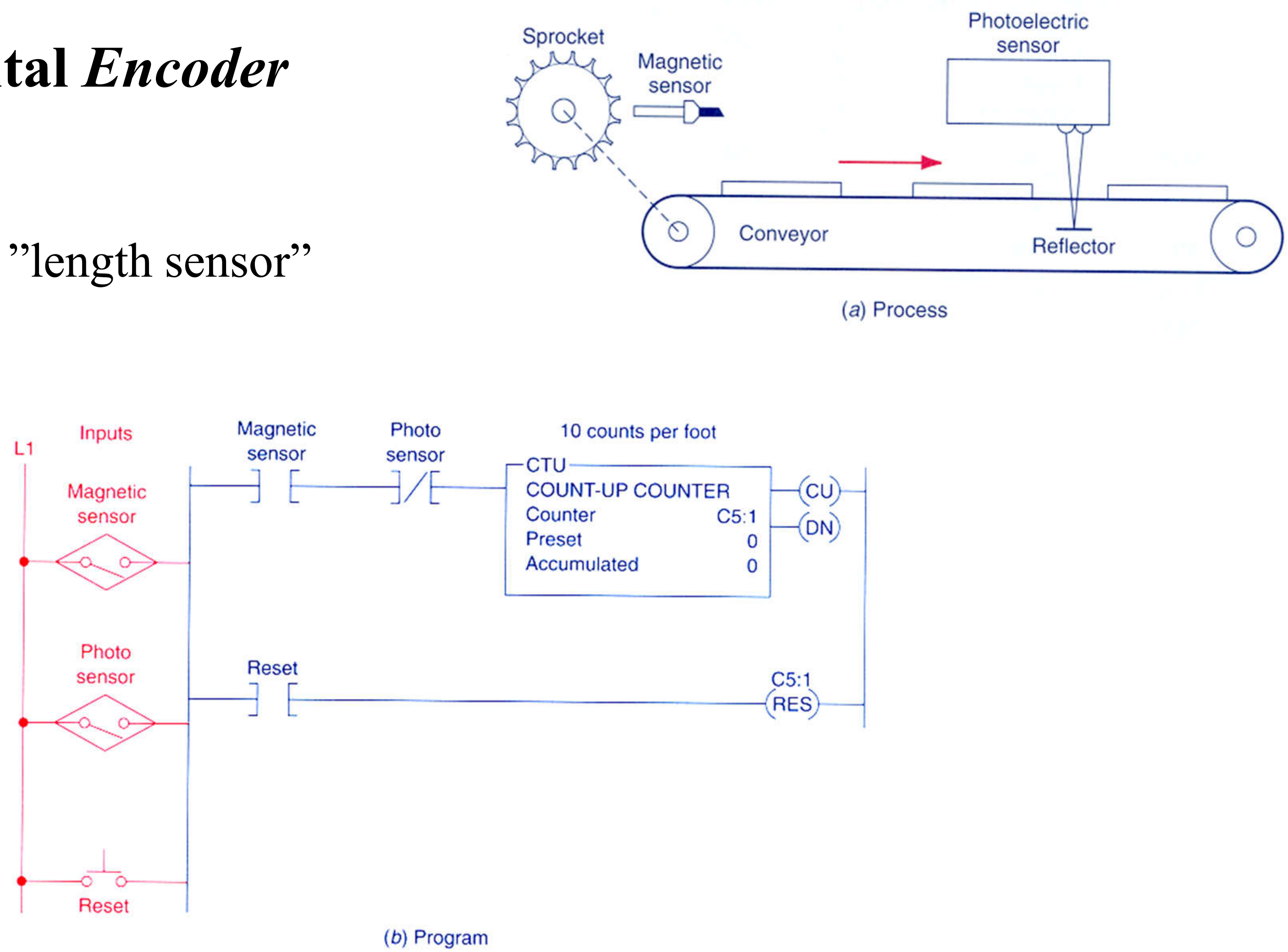


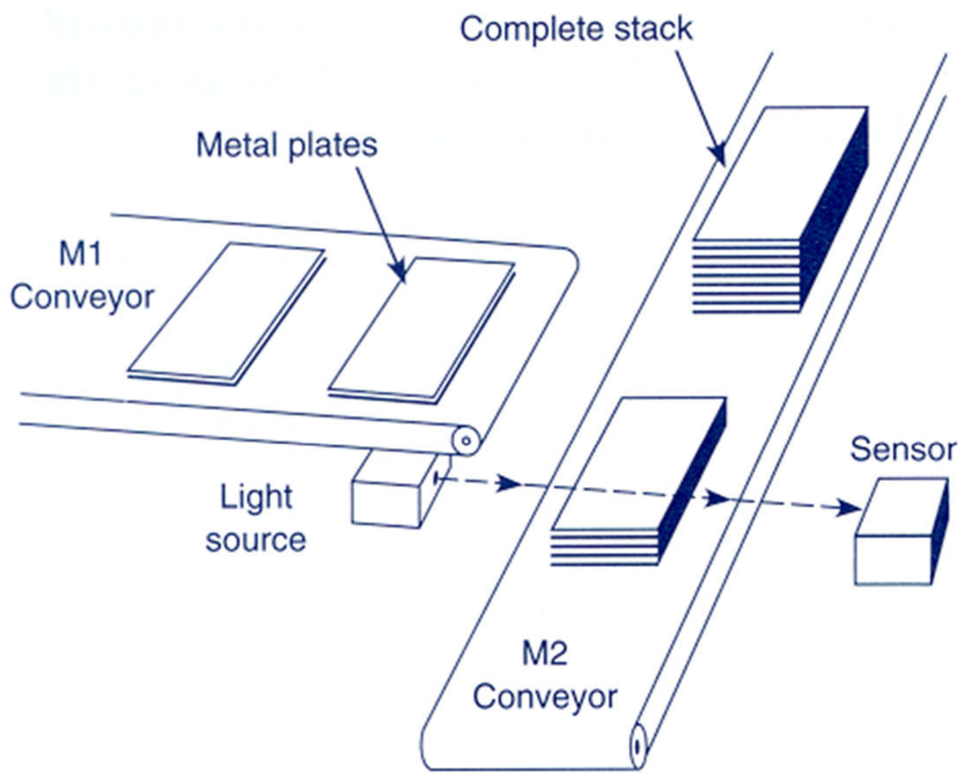
Fig. 8-27
Counter used for length measurement.

Ladder diagram

Example with counters and timers (cont.):

Specs:

- Starts M1 conveyor upon pushing button .
- After 15 plates stops M1 and starts conveyor M2 .
- M2 operates for 5 seconds and then stops.
- Restart sequence.



(a) Process

Ladder diagram

Example with counters and timers (cont.):

Specs:

• Starts M1 conveyor upon pushing button .

• After 15 plates stops M1 and starts conveyor M2 .

• M2 operates for 5 seconds and then stops.

• Restart sequence.

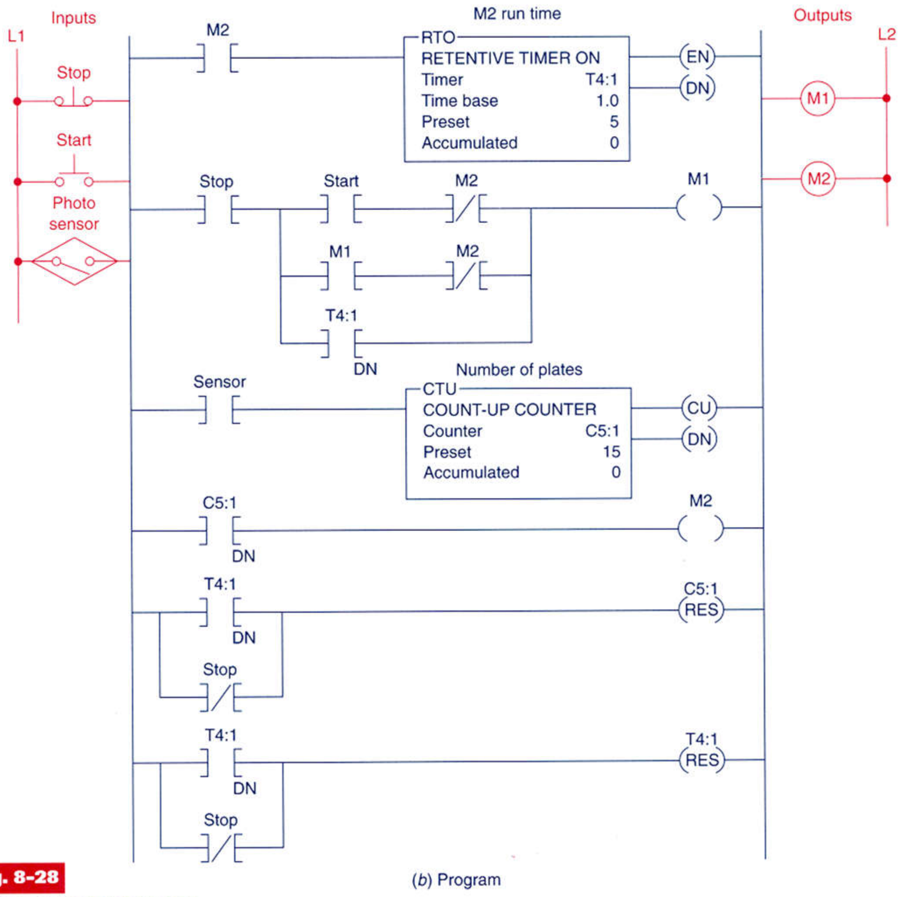


Fig. 8-28
Automatic stacking program.

Ladder diagram

Example with counters and timers (cont.):

Specs:

- Starts M1 conveyor upon pushing button .
- After 15 plates stops M1 and starts conveyor M2 .
- M2 operates for 5 seconds and then stops.
- Restart sequence.

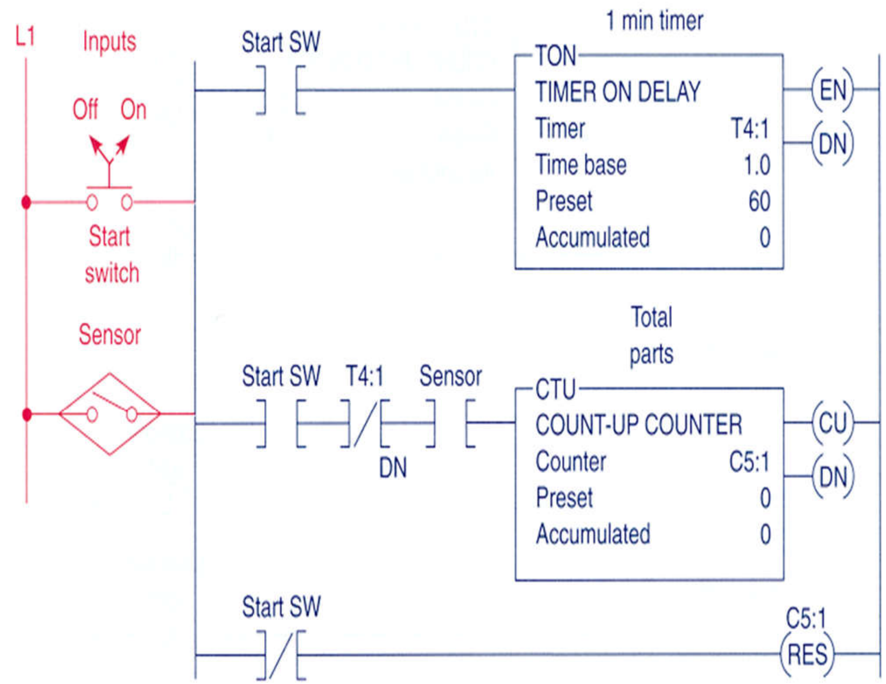


Fig. 8-30

Product flow rate program.

Ladder diagram

Example with counters and timers (cont.):

To use a timer to command a counter, to implement large periods of time.

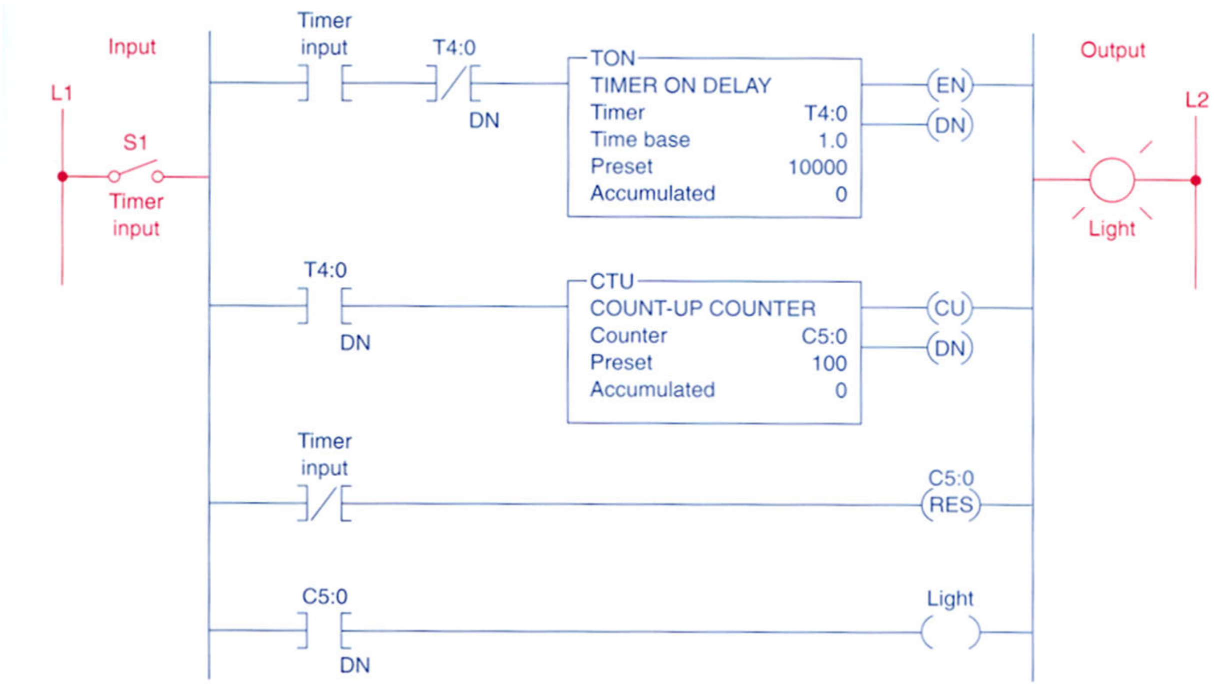
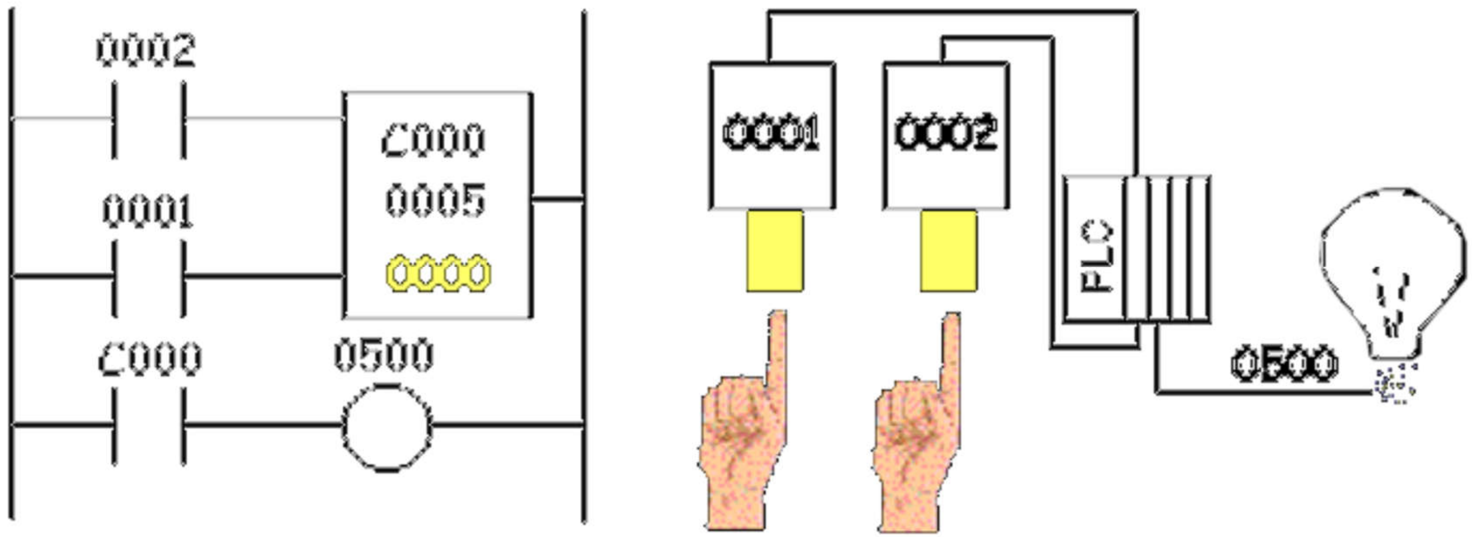


Fig. 8-31
Timer driving a counter to produce an extremely long time-delay period.

Ladder diagram

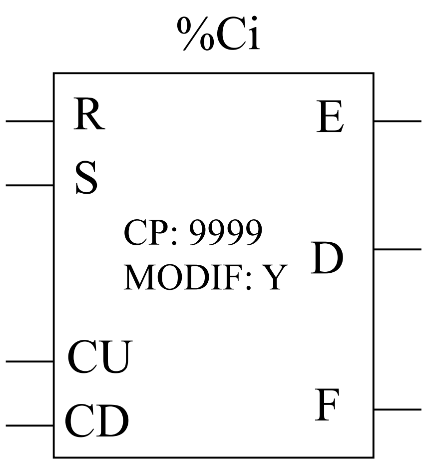
Counters

Example:



Ladder diagram

Counters in PL7

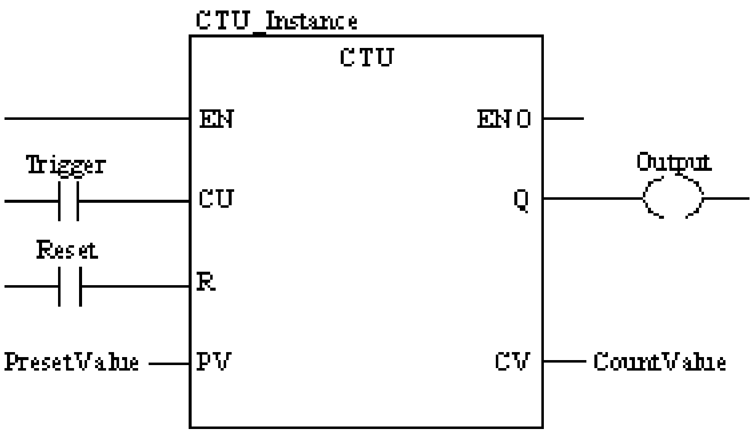


Characteristics:

Identifier: %Ci	0..31 in the TSX37	
Value progr.:	%Ci.P	0...9999 (def.)
Value Actual:	%Ci.V	0...Ci.P (only to be read)
Modifiable:	Y/N	can be modified from the console
Inputs:	R	Reset Ci.V=0
	S	Preset Ci.V=Ci.P
	CU	*Count Up*
	CD	*Count Down*
Outputs:	E	Overrun %Ci.E=1 %Ci.V=0->9999
	D	Done %Ci.D=1 %Ci.V=Ci.P
	F	Full %Ci.F=1 %Ci.V=9999->0

Ladder diagram

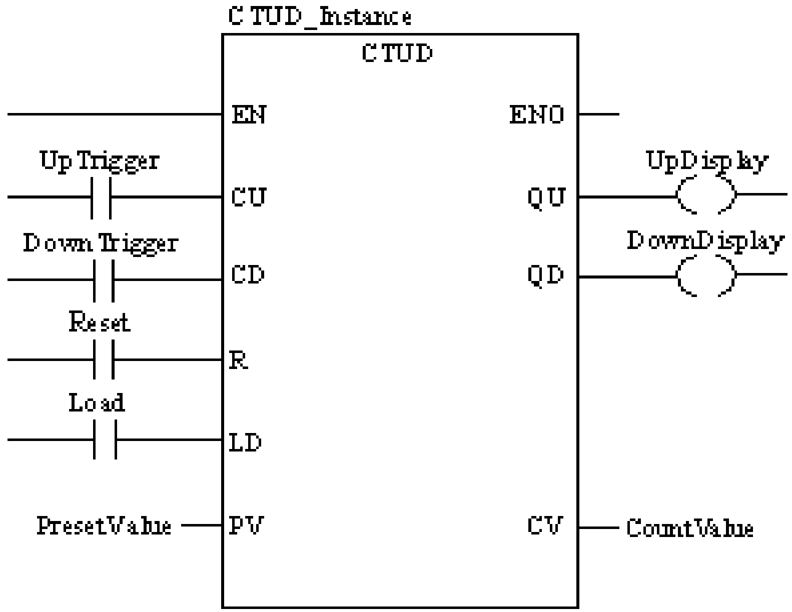
Counters in Unity Pro



CU "0" to "1" => CV is incremented by 1

CV ≥ PV => Q:=1

R=1 => CV:=0



CU "0" to "1" => CV is incremented by 1
CD "0" to "1" => CV is decremented by 1

CV ≥ PV => QU:=1
CV ≤ 0 => QD:=1

R=1 => CV:=0 **LD=1** => CV:=PV
R has precedence over LD

NOTE: counters are saturated such that no overflow occurs

Ladder diagram

Numerical Processing

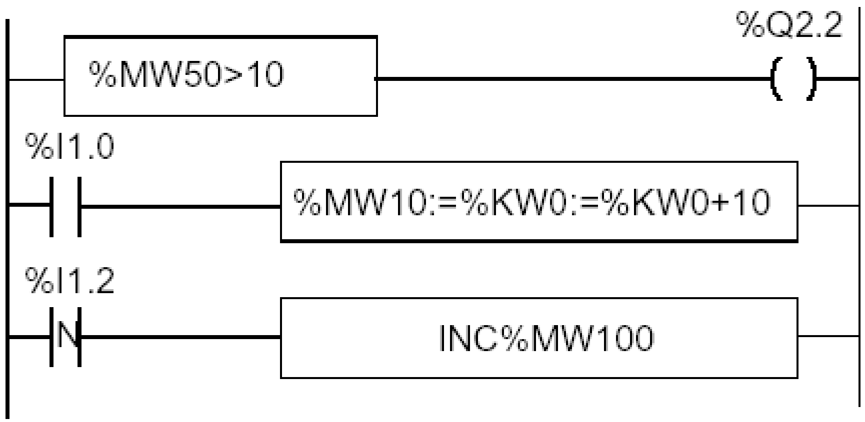
Algebraic / Arithmetic and Logic Functions

Note:

%M	memory
%K	constant
%S	system

Compare block →

Operate block →



Ladder diagram

Numerical Processing

Arithmetic Functions

+	addition of two operands	**SQRT**	square root of an operand
-	subtraction of two operands	**INC**	incrementation of an operand
*	multiplication of two operands	**DEC**	decrementation of an operand
/	division of two operands	**ABS**	absolute value of an operand
REM	remainder from the division of 2 operands		

Operands

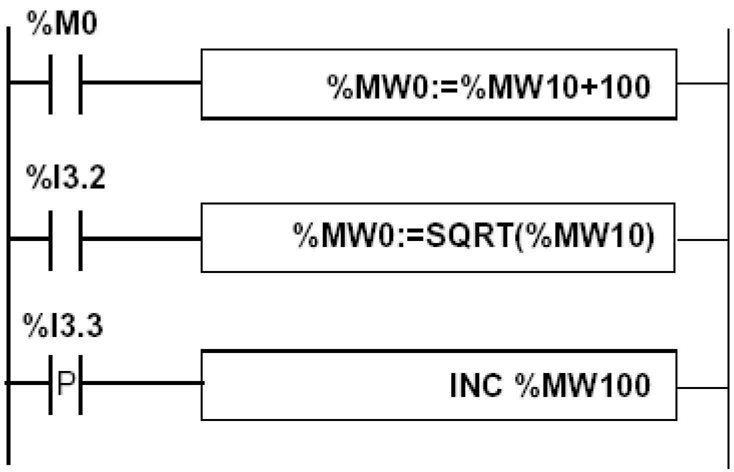
Type	Operand 1 (Op1)	Operand 2 (Op2)
Indexable words	%MW	%MW,%KW,%Xi.T
Non-indexable words	%QW,%SW,%NW,%BLK	Imm.Val.,%IW,%QW,%SW,%NW, %BLK, Num.expr.
Indexable double words	%MD	%MD,%KD
Non-indexable double words	%QD,%SD	Imm.Val.,%ID,%QD,%SD, Numeric expr.

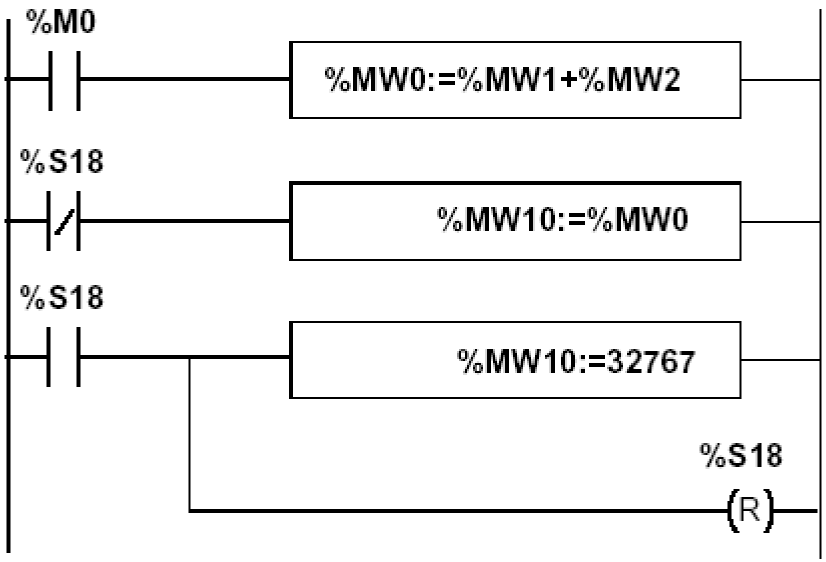
Ladder diagram

Numerical Processing

Example:

Arithmetic functions





Use of a system variable:

%S18 – flag de overflow

Ladder diagram

Numerical Processing

Logic Functions

AND	AND (bit by bit) between two operands
OR	logical OR (bit by bit) between two operands
XOR	exclusive OR (bit by bit) between two operands
NOT	logical complement (bit by bit) of an operand

Comparison instructions are used to compare two operands.

- **>**: tests whether operand 1 is greater than operand 2,
- **>=**: tests whether operand 1 is greater than or equal to operand 2,
- **<**: tests whether operand 1 is less than operand 2,
- **<=**: tests whether operand 1 is less than or equal to operand 2,
- **=**: tests whether operand 1 is different from operand 2.

Operands

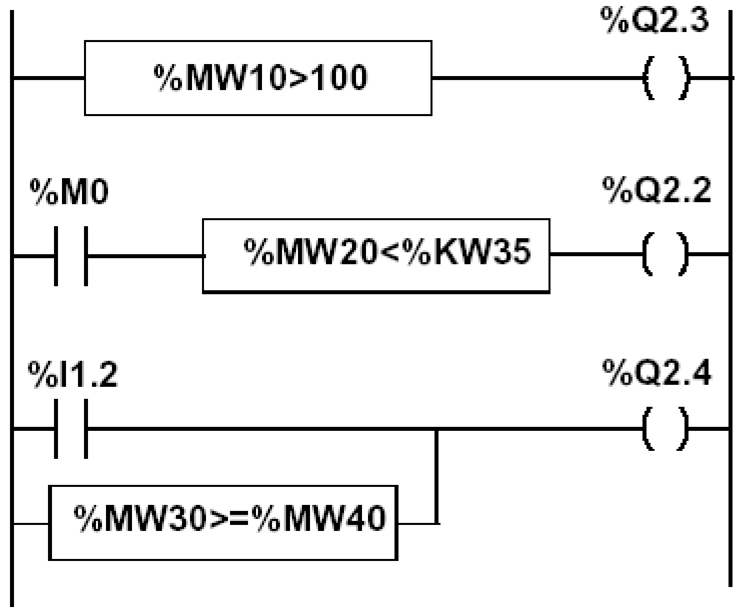
Type	**Operands 1 and 2 (Op1 and Op2)**
Indexable words	%MW,%KW,%Xi.T
Non-indexable words	Imm.val.,%IW,%QW,%SW,%NW,%BLK, Numeric Expr.
Indexable double words	%MD,%KD
Non-indexable double words	Imm.val.,%ID,%QD,%SD,Numeric expr.

Ladder diagram

Numerical Processing

Example:

Logic functions



Ladder diagram

Numerical Processing

Priorities on the execution of the operations

Rank	Instruction
1	Instruction to an operand
2	*,/,REM
3	+,-
4	<,>,<=,>=
5	=,<>
6	AND
7	XOR
8	OR

Ladder diagram

Structures for Control of Flux

JUMP instructions:

Conditional and unconditional

Jump instructions are used to go to a programming line with an %Li label address:

- **JMP**: unconditional program jump
- **JMPC**: program jump if the instruction's Boolean result from the previous test is set at 1
- **JMPCN**: program jump if the instruction's Boolean result from the previous test is set at 0. %Li is the label of the line to which the jump has been made (address i from 1 to 999 with maximum 256 labels)

Ladder diagram

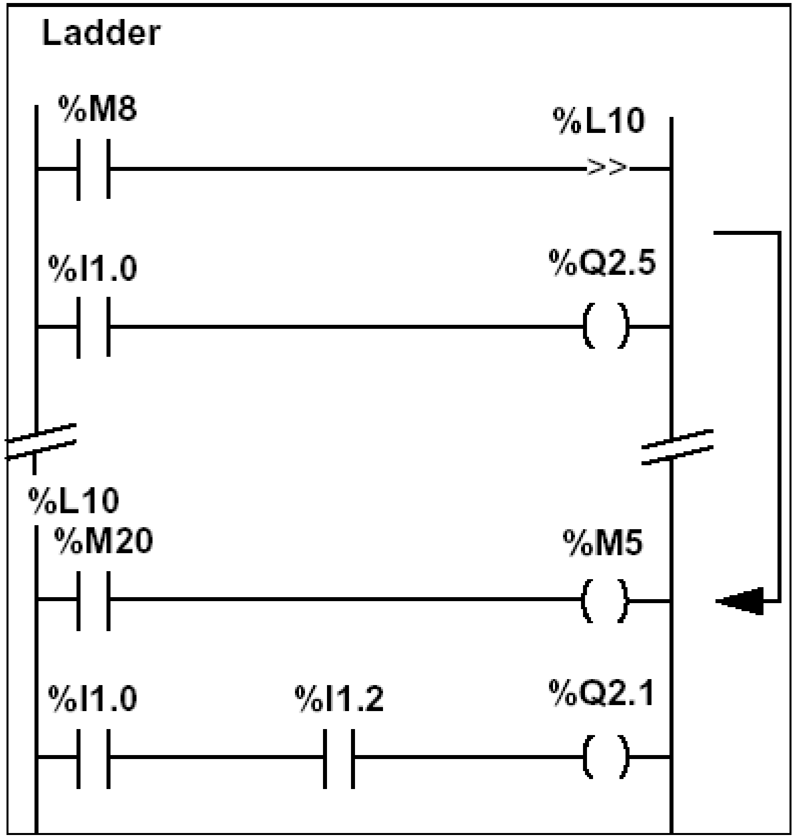
Structures for Control of Flux

Example:

Use of jump instructions

Attention to:

- **INFINITE LOOPS ...**
- **It is not a good style of programming!...**
- **Does not improove the legibility of the proposed solution.**

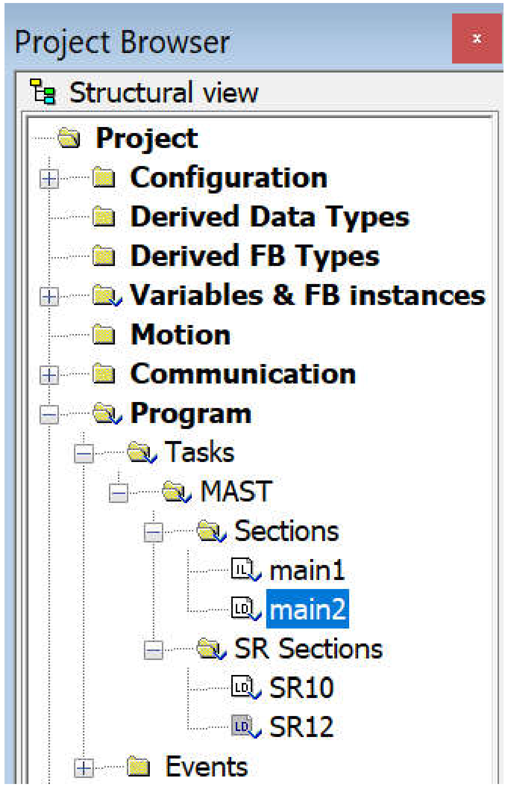


Ladder diagram

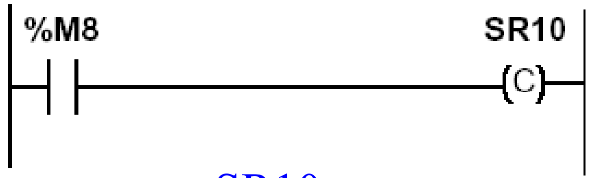
Structures for Control of Flux

Subroutines

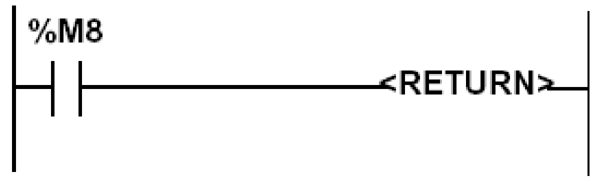
Call and Return

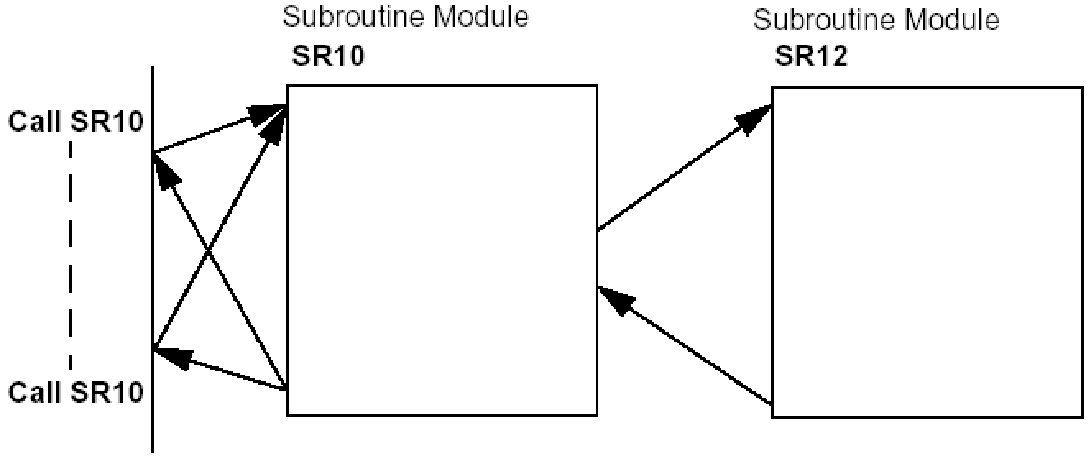


main2



SR10

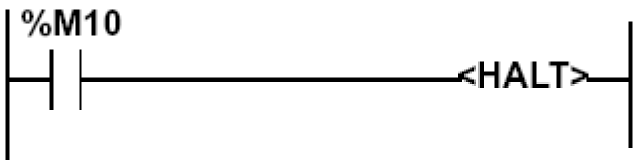




Ladder diagram

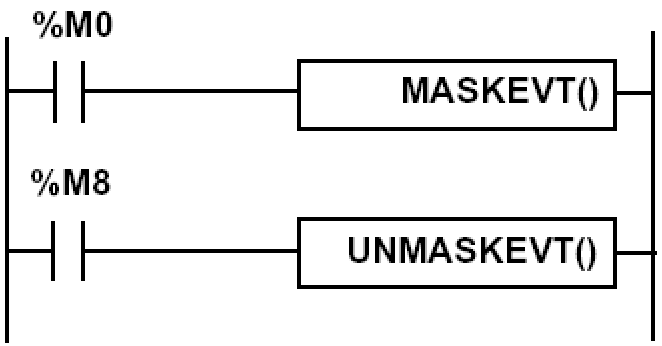
Structures for Control of Flux

Halt



Stops all processes!

Events masking



Ladder diagram

There are other advanced instructions (see manual)

- **Monostable**
- **Registers of 256 words (LIFO ou FIFO)**
- ***DRUMs***
- **Comparators**
- ***Shift-registers***

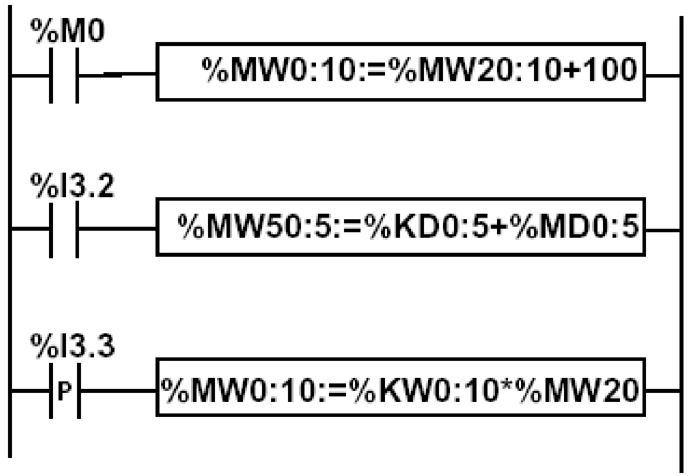
...

- **Functions to manipulate *floats***
- **Functions to convert bases and types**

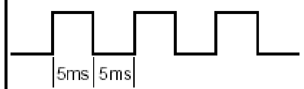
Ladder diagram

Numerical Tables

Type	Format	Maximum address	Size	Write access
Internal words	Simple length	%MWi:L	i+L<=Nmax (1)	Yes
	Double length	%MWDi:L	i+L<=Nmax-1 (1)	Yes
	Floating point	%MFi:L	i+L<=Nmax-1 (1)	Yes
Constant words	Single length	%KWi:L	i+L<=Nmax (1)	No
	Double length	%KWDi:L	i+L<=Nmax-1 (1)	No
	Floating point	%KFi:L	i+L<=Nmax-1 (1)	No
System word	Single length	%SW50:4 (2)	-	Yes



Ladder diagram Schneider Micro PLC, system information: system ***bits***

Bit	Function	Description	Initial state	TSX37	TSX57
%S0	Cold start	Normally on 0, this bit is set on 1 by: ● loss of data on power restart (battery fault), ● the user program, ● the terminal, ● cartridge uploading, ● pressing on the RESET button. This bit goes to 1 during the first complete cycle. It is reset to 0 before the following cycle. (Operation)	0	YES	YES
%S1	Warm restart	Normally on 0, this bit is set on 1 by: ● power restart with data save, ● the user program, ● the terminal. It is reset to 0 by the system at the end of the first complete cycle and before output is updated. (Operation)	0	YES	YES
%S4	Time base 10ms	An internal timer regulates the change in status of this bit. It is asynchronous in relation to the PLC cycle. Graph : 	-	YES	YES
%S5	Time base 100 ms	Idem %S4	-	YES	YES
%S6	Time base 1 s	Idem %S4	-	YES	YES
%S7	Time base 1 mn	Idem %S4	-	YES	YES

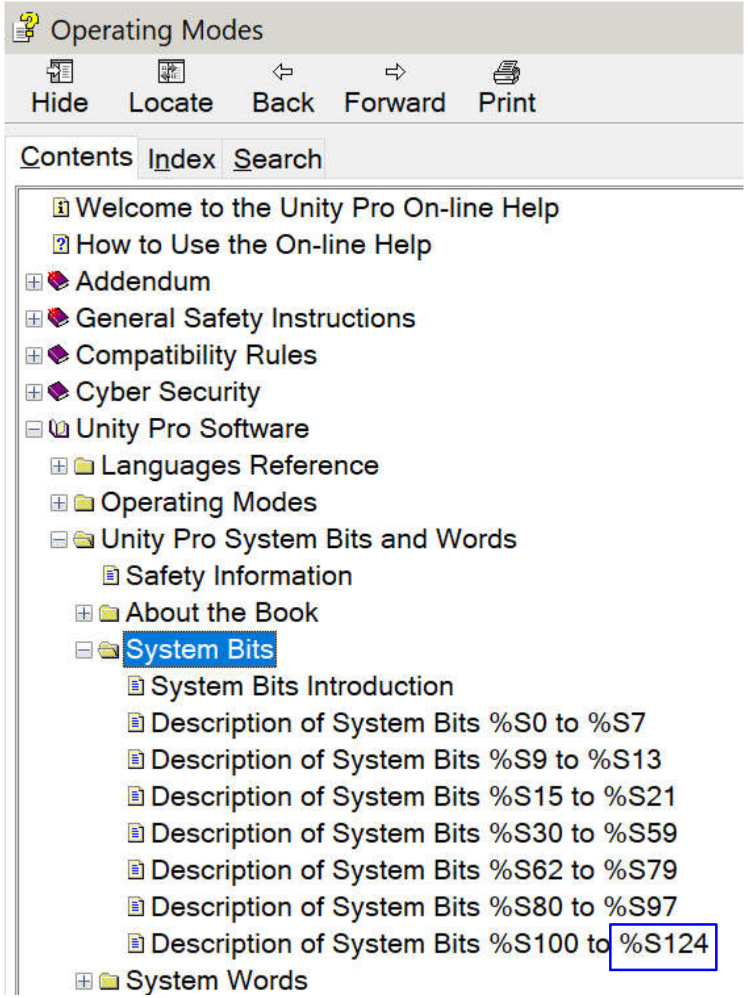
See manual for the remaining 100 bits generated...

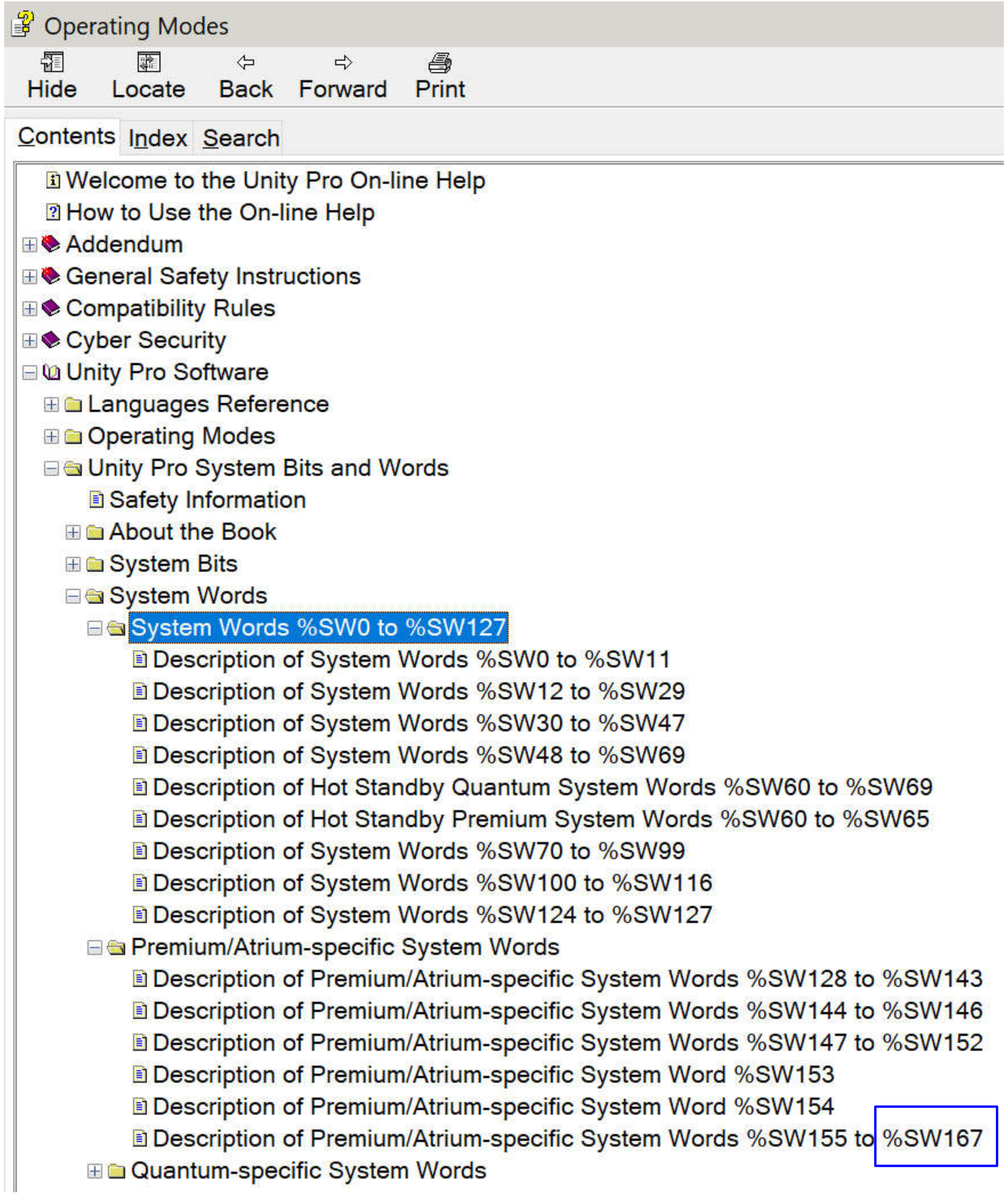
Ladder diagram Schneider Micro PLC, System information: system ***words***

Words	Function	Description	Management
%SW0	Master task scanning period	The user program or the terminal modify the duration of the master task defined in configuration. The duration is expressed in ms (1.255 ms) %SW0=0 in cyclic operation. On a cold restart: it takes on the value defined by the configuration.	User
%SW1	Fast task scanning period	The user program or the terminal modify the duration of the fast task as defined in configuration. The duration is expressed in ms (1.255 ms) On a cold restart: it takes on the value defined by the configuration.	User
%SW8	Acquisition of task input monitoring	Normally on 0, this bit can be set on 1 or 0 by the program or the terminal. It inhibits the input acquisition phase of each task. • %SW8:X0 =1 assigned to MAST task: outputs linked to this task are no longer guided. • %SW8:X1 =1 assigned to FAST task: outputs linked to this task are no longer guided.	User
%SW9	Monitoring of task output update	Normally on 0, this bit can be set on 1 or 0 by the program or the terminal. Inhibits the output updating phase of each task. • %SW9:X0 =1 assigned to MAST task: outputs linked to this task are no longer guided. • %SW9:X1 =1 assigned to FAST task: outputs linked to this task are no longer guided.	User
%SW10	First cycle after cold start	If the bit for the current task is on 0, this indicates that the first cycle is being carried out after a cold start. • %SW10:X0: is assigned to the MAST Master task • %SW10:X1: is assigned to the FAST fast task	System
%SW11	Watchdog duration	Reads the duration of the watchdog as set in configuration. It is expressed in ms (10…500 ms).	System

See manual for the remaining 140 words generated...

Schneider Premium
System information:
system ***bits*****,** system ***words***



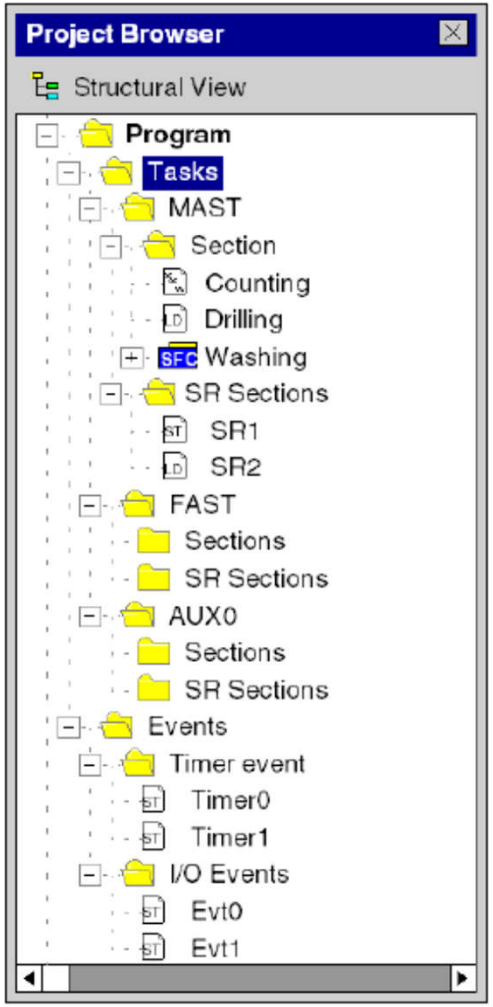


%S0 COLDSTART	Function	Cold start		
	Initial State	1 (1 cycle)		
	Platforms	**M340:** Yes **M580:** Yes	**Quantum:** Yes **Momentum Unity:** Yes	**Premium:** Yes **Atrium:** Yes
	Normally on 0, this bit is set on 1 by: • power restoral with loss of data (battery fault found) • the user program • the terminal • a change of cartridge (PCMCIA on Premium and Quantum) This bit is set to 1 during the first complete restored cycle of the PLC either in RUN or in STOP mode. It is reset to To detect the first In Safe mode, this %S0 is not always needed, %S21 sh For details on ope • *Premium, Qua* • or *Modicon M3* • or *BME P58 xx*			

%S1 WARMSTART	Function	Warm restart		
	Initial State	0		
	Platforms	**M340:** Yes **M580:** Yes	**Quantum:** Yes[1] **Momentum Unity:** Yes	**Premium:** Yes **Atrium:** Yes
		(1) except for safety PLCs		
	Normally at 0, this bit is set to 1 by: • power is restored with data save, • the user program, • the terminal, It is reset to 0 by the system at the end of the first complete cycle and before the outputs are updated. This bit is not available on Quantum Safety PLCs. %S1 is not always set in the first scan of the PLC. If a signal set for every start of the PLC is needed, %S21 should be used instead.			

%SW0 MASTPERIOD *Not the cyclic period*	Function	Master task scanning period
	Initial State	0
	Platforms	**M340:** Yes **M580:** Yes **Quantum:** Yes[1] **Momentum Unity:** Yes **Premium:** Yes **Atrium:** Yes **(1)** except for safety PLCs
		This word is used to modify the period of the master task via the user program or via the terminal. The period is expressed in ms (1...255 ms) %SW0=0 in cyclic operation. On a cold restart: it takes the value defined by the configuration.
%SW1 FASTPERIOD	Function	FAST task scanning period
	Initial State	0
	Platforms	**M340:** Yes **M580:** Yes **Quantum:** Yes[1] **Momentum Unity:** No **Premium:** Yes **Atrium:** Yes **(1)** except for safety PLCs
		This word is used to modify the period of the FAST task via the user program or via the terminal. The period is expressed in milliseconds (1...255 ms). On a cold restart, it takes the value defined by the configuration. **NOTE**: This word is not available on Quantum safety PLCs.

Ladder diagram Software Organization



A program can be built from:
Tasks, that are executed cyclically or periodically.

Tasks **MAST** / FAST / AUX are built from:
Sections
Subroutines
Event processing, that is carried out before all other tasks.

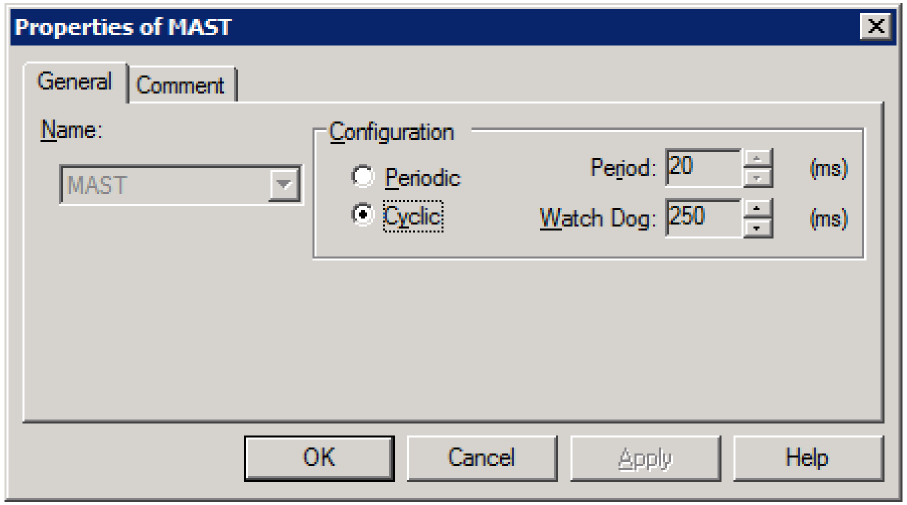
Event processing is built from:
Sections for processing time controlled events
Sections for processing hardware controlled events

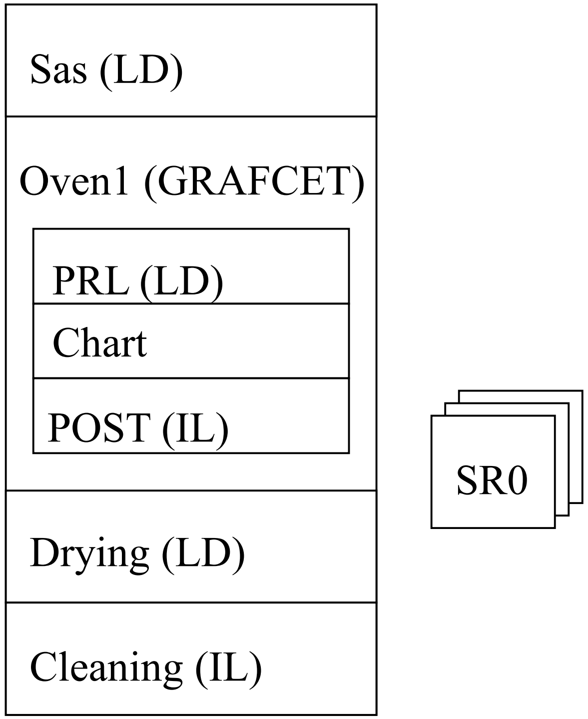
Unity - Project Browser

Ladder diagram Software Organization

MAST – Master Task Program

- **Composed by sections**
- **Execution Cyclic or Periodic**





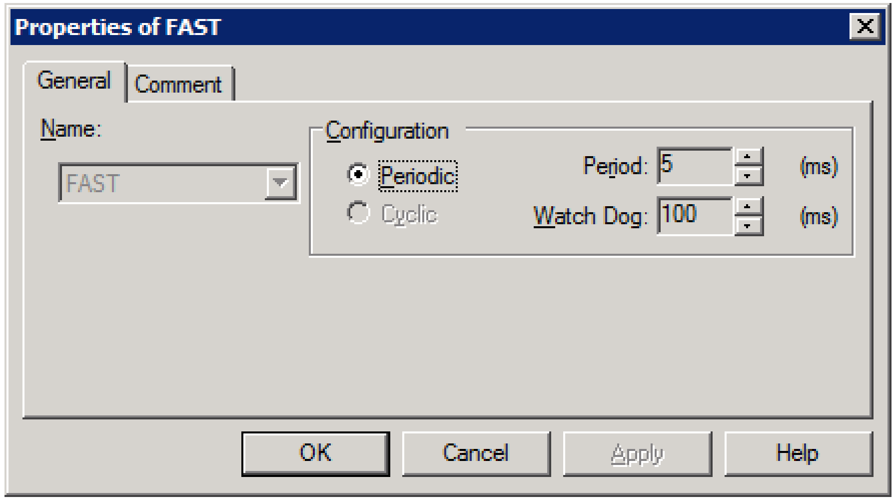
Cyclical execution consists of stringing cycles together one after the other with no waiting time between the cycles.

In **Periodic** mode, you determine a specific time (period) in which the master task must be executed. If it is executed under this time, a waiting time is generated before the next cycle. If it is executed over this time, a control system indicates the overrun. If the overrun is too high, the PLC is stopped.

Ladder diagram Software Organization

FAST – **Fast Task Program**

Priority greater than MAST



- Executed Periodically (1-255ms)
- Verified by a *Watchdog,* impacts on %S11
- %S31 *Enables* or *disables* a FAST
- %S33 gives the execution time for FAST

Ladder diagram Software Organization

Event Processes – Processes that can react to external changes (16 in the Micro 3722 EV0 to EV15)

Priority greater than MAST and FAST!

Event Generators

- **Inputs 0 to 3 in module 1, given transitions**
- **Counters**
- **Upon telegrams reception**
- **%S38 *Enables* or *disables* event processes**

(also with MASKEVT() or UNMASKEVT())

Ladder diagram Development tools

Each PLC has limitations in terms of connections

Example:

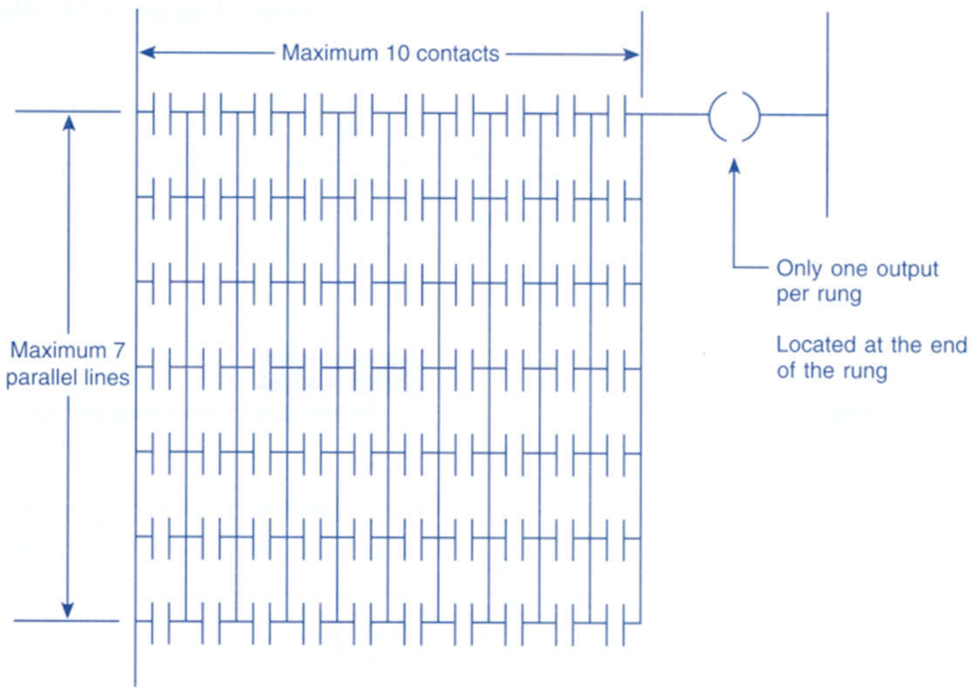
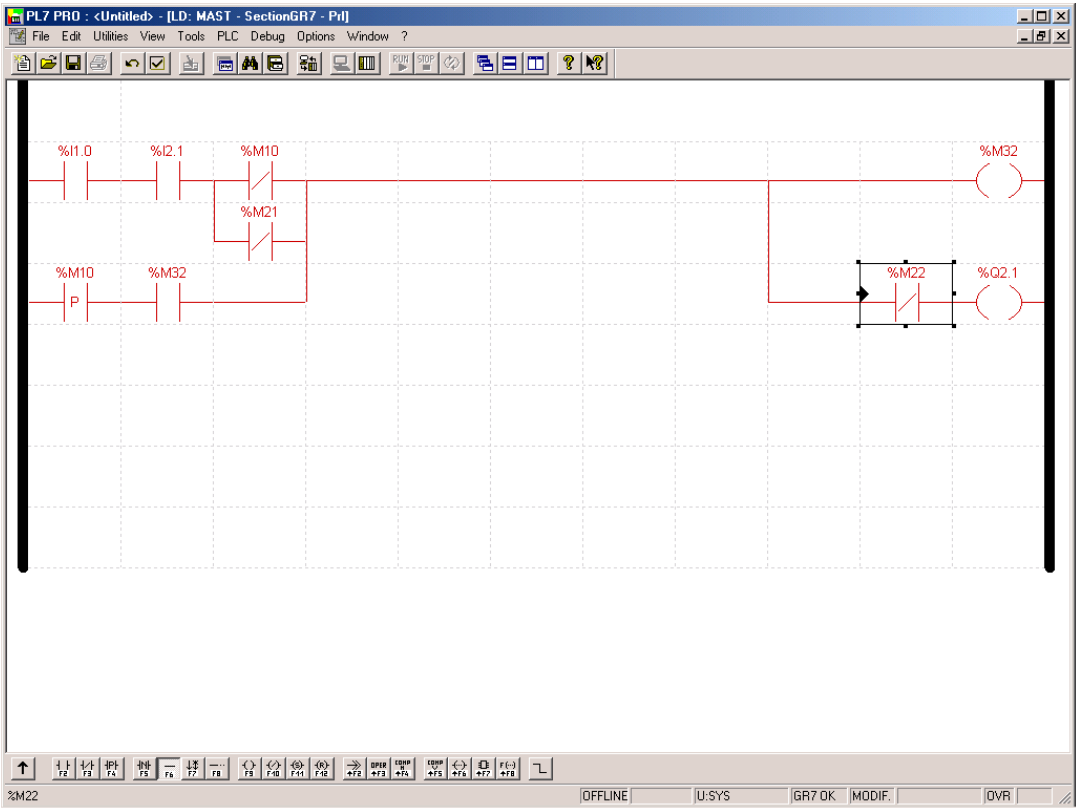


Fig. 5-27

Typical PLC matrix limitation diagram. The exact limitations are dependent on the particular type of PLC used. Programming more than the allowable series elements, parallel branches, or outputs will result in an error message being displayed.

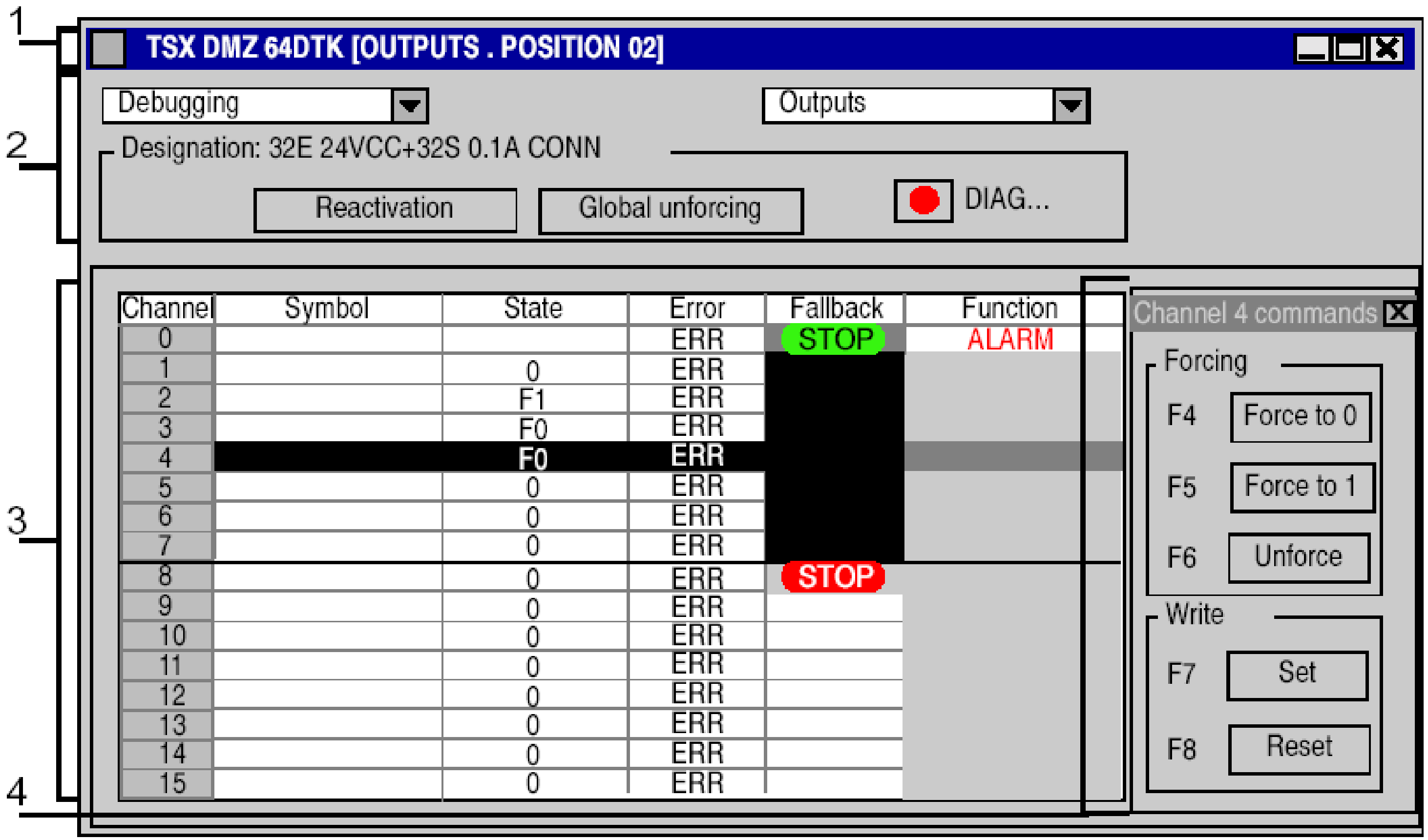
Ladder diagram Development tools

It is important to learn the potentialities and ...
the limitations of the developing tools,
i.e. ***STUDYING the manuals is a MUST.***



Ladder diagram   Development tools

Last but not least, ***learn how to develop and debug programs***
(and how to do some fine tuning).



Ladder diagram **Development tools**

Last but not least, ***learn how to develop and debug programs***
(and how to do some fine tuning).